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VISUAL PERCEPTION OF SPACE*

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It is the purpose of this paper (1) to show how one can proceed in selecting a set of parameters for describing physical and visual space, and (2) to outline the basic principles for relating perceived space to physical space.

THE COORDINATES OF PHYSICAL SPACE

It should be explained at the outset that consideration will be limited primarily to the horizontal plane which contains the centers of rotation and is perpendicular to the face plane. This plane is represented in Figure 1 on an x, y diagram. The x axis is the perpendicular bisector of the base line connecting the centers of rotation (C_L and C_R) of the

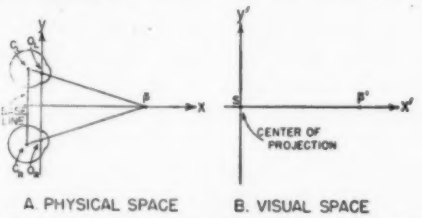

Fig. 1. Coordinates of physical and visual space for the horizontal plane.

two eyes. Consideration will be further limited to the situations in which the primary lines of sight converge on a point $\overline{P}$ on the x axis, so that the y axis can be drawn through the centers of the two entrance pupils (O_R and O_L).

The plane normal to the x, y plane and intersecting it at the x axis can be designated the x, z plane.

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THE COORDINATES OF VISUAL SPACE

For the typical observer the x, y plane in physical space is represented in visual space by the x′, y′ plane. This means that all points in the x, y plane are imaged on the horizontal meridians of the two retinas and are perceived as lying in a single plane in visual space. This implies that the eyes are free from cyclophoria. The center of projection is the origin of the x′, y′ coordinates and the x′ axis represents the perceived direction of the point $\bar{P}$; i.e., the image $\bar{P}'$ of $\bar{P}$ lies on the x′ axis.

The x′, z′ plane is normal to the x′, y′ plane and the two planes intersect at the x′ axis.

COINCIDENCE OF THE X, Y AND THE X′, Y′ PLANES

The fact that the x, y and the x′, y′ planes coincide can be deduced from the following observation. The subject looks at a point on a wall about 10 feet away with screens interposed to prevent his seeing the point at which the wall joins the floor. The point on the wall can be moved up or down until the subject reports that it is located at eye-level. At the same time he can hold in his hands a piece of glass with a straight line drawn on it and hold the glass so that the line appears to be horizontal, and he can tip his head to his right or left shoulder until the dextrocular and sinistrocular images of the horizontal line appear to coincide. The piece of glass can then be raised or lowered until it lies in the same horizontal plane as the point on the distant wall. The judgment that the line is horizontal and that the point on the distant wall lies at eye level involves the coordination of visual perception with the sense of gravity which is made possible through the other sense organs. The fact that the plane defined by the line on a piece of glass and the point on the distant wall are precisely horizontal or very nearly so constitutes proof that the x′, y′ plane is horizontal with respect to one's sense of gravity when the x, y plane is horizontal.

The above demonstration proves that the x, y plane is parallel to the x′, y′ plane.

The fact that one can look at the image of the root of his nose in a vertical mirror and can reach behind the mirror and place his finger on the image of the root of his nose, constitutes the evidence that the x′, y′ plane coincides with the x, y plane.

DEPENDENCE OF PERCEIVED SPACE ON THE POINT OF FIXATION

There is a unique correlation between physical and perceived space for every new point of fixation.

Assuming that the head is fixed in physical space, the eyes can

turn and converge their lines of sight upon each of the multitude of points within the three dimensional binocular field of fixation. The field of fixation of a single eye can be defined as the solid angle which is fixed with respect to the head and has its apex at the center of rotation. It is the space which contains all possible positions of the primary line of sight. The two cone shaped spaces which constitute the field of fixation of the two eyes intermesh and the intermeshing parts constitute the binocular field of fixation. In the normal use of the two eyes the two primary lines of sight converge on a common fixation point; and they jump from one fixation point to another. Since the relation between perceived space and physical space is apt to change from moment to moment, any concept of a relation between perceived and physical space must be one which applies to a given moment. In the present paper consideration is limited to the relationship that exists at a given moment during a period of steady fixation.

It has not been the intention to imply that space as perceived while the eyes are fixing a given point is not affected by what was perceived during the previous fixation period. There is a great deal of carry over, but the problem has to be analyzed at each fixation point.

CENTER OF PROJECTION

There exists a single point called the center of projection from which the impressions of the two eyes are projected into space.

One-eyed individuals and squinters with or without anomalous correspondence present special problems. Consequently consideration is limited here to what we might call a normal observer.

There is a method which may be claimed to be valid for locating the center of projection. It involves placing just below the level of the eyes a board which makes contact with the face and is notched for the nose, so that it is impossible for the observer to see the space below the board. See Figure 2A. The observer is required to fixate a distant point $\bar{P}$ and observes at the same time a double image of a vertical rod P which is mounted to the board. The observer then holding a pointer with both hands is required to locate the positions (P'_R and P'_L) of the two perceived rods. In this experiment one can assume (1) that the single image of the distance point $\bar{P}'$ which is seen with the fovea of each eye is projected in a direction parallel to the bisector of the angle of convergence for $\bar{P}$ and also (2) that the perceived angle ψ between the image P' of the distant object and the image P' of the near object seen by each eye is the same as the physical angle ψ subtended by the two objects at the entrance pupil of the eye. One can, therefore, locate the position of the center of projection by drawing a line

through the left hand image P'_R which makes an angle ψ'_R with the bisector of the angle of convergence for $\bar{P}$ equal to ψ_R and a second line through the right hand image P'_L which makes an angle ψ'_L with the bisector of the angle of convergence for $\bar{P}$ equal to ψ_L. The intersection S of these two lines represents the center of projection. It is found by this procedure to be located near the midpoint of the inter-pupillary line.

It will be further assumed for the purpose of this paper that the center of projection will move along with the midpoint of the inter-pupillary line as the eyes change convergence and direction of fixation.

The beauty of the method described above is that the subject is not required to pass any judgments, either directly or indirectly, upon where his center of projection is located. If as in Figure 2 the vertical

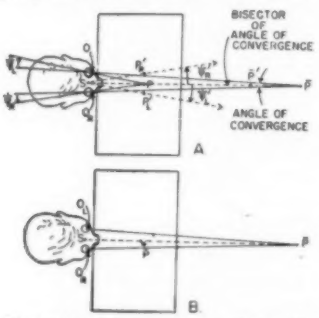

Fig. 2. Methods of locating the center of projection.

rod is removed from the board and the observer is asked to hold up the pointer under the board so that it falls directly between him and the distant object he can actually locate the pointer at a point P and after having done this he will feel that he has fulfilled the instruction, but by permitting himself to do this he has allowed the instructor to trick him into indicating his notion about where his center of projection is located. The experimenter assumes that the center of projection (S) is located on the line through $\bar{P}$ and P. We sometimes jokingly refer to the little man inside the observer's head who does his seeing for him, and this concept has a real application here: because an observer will hold the pointer and not let it veer as much as one millimeter to the right or to the left and specify that the pointer lies exactly between him and the distant object. This must mean that unwittingly he regards himself to be a mathematical point without dimensions. A person who happens to have a strongly dominant eye may be apt to place the pointer on the line with the dominant eye and the distant object. This is probably due to the fact that he is so accustomed to

looking through keyholes and knot holes with his dominant eye that when he is called upon to point out that part of his anatomy which constitutes his center of projection he naturally picks the eye which he uses in a monocular situation. He literally visualizes the little man in his head as peering out through the pupil of his dominant eye. The fact that the observer arbitrarily picks some point of his anatomy and calls it his center of projection is borne out by the fact that as soon as the situation is explained, he can place the pointer on line with his right eye, left eye, right ear, left ear or the center of his nose. Hence in the original setting it cannot be claimed that he has located a center of projection; he has merely indicated what he unwittingly considers to be his center of projection. Of this, the subject cannot have direct knowledge. To locate the center of projection one must use a more indirect method as described above.

LINES OF SIGHT IN VISUAL SPACE

The lines of sight constitute geodesics (straight lines) in visual space.

If a round aperture which is larger than the entrance pupil is centered on a line which passes through the center of the entrance pupil and a distant point, the point will appear at the center of the hole regardless of its distance from the entrance pupil. Points on a given line of sight produce retinal images clear or blurred which are all centered around the same point, and it is reasonable to expect that images falling on the same retinal point can have a single direction of projection.

CORRESPONDING POINTS OF THE TWO RETINAE

The images formed on corresponding points of the two retinae are projected in the same direction and each pair of corresponding lines of sight is represented by the same geodesic in visual space.

There is probably an anatomical basis for the relation which exists between corresponding points of the two retinae in a normal subject, but this point need not be argued, nor is it necessary at this point to consider the special problem presented by anomalous correspondence. If the primary lines of sight of the two eyes actually converge on a common point and if the eyes are free from cyclophoria, not only do the images of the point of fixation fall on corresponding points but also a number of other points can be found in physical space which will produce images on corresponding points of the two retinas. The surface which contains these points is called the horopter (see Figure 3). I will use this term horopter in this sense in this paper and thus dis-

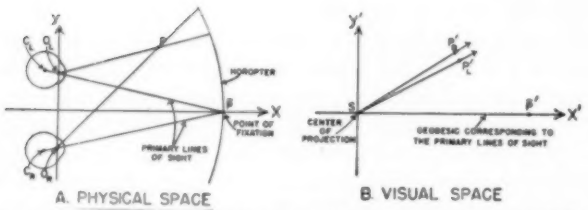

Fig. 3. Crossed physiological diplopia for a point between the eyes and the horopter.

tinguish it from what will be discussed later as an apparent frontal plane. Actually the word horopter is also frequently used in a broader sense to include the apparent frontal plane through the point of fixation as well as the surface containing points which stimulate corresponding retinal points.

One of the consequences of retinal correspondence is that a point (P, Figure 3) in front of or behind the horopter which projects its images on non-corresponding points must be seen as double (see Figure 3). One of the unsolved problems is that a point must be displaced considerably in front of or behind the horopter before it will be actually seen as double. This occurs in spite of the fact that the images formed on the two retinae fall on non-corresponding points and are projected to disparate points of the visual cortex. This fact of single vision with disparate cortical points can probably be explained by assuming that the impression transmitted from one of the retinae is inhibited, but there are many writers, e.g., Verhoeff[1], who claim that there may be an actual fusion of images formed on noncorresponding points of the two retinae. A more important aspect of the problem so far as the present paper is concerned is whether the single image which is seen is projected from the center of projection in a direction corresponding to the image on the right or left retina or in a direction which is intermediate between them.

The problem is illustrated by the stereogram in Figure 4 where the upper line represents a far object and the lower line a near one. The first casual observation is that the upper and lower lines are seen single and lie in the same direction from a point midway between the

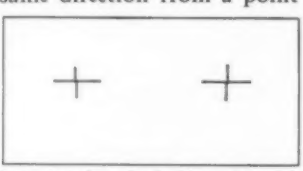

Fig. 4. Stereogram for demonstrating single binocular vision with non-corresponding points of the two retinæ.

two eyes and this is especially true if the eyes keep changing convergence from one to the other. But if I attempt to hold convergence on one while I observe the other passively, I see periodically a double image or only one of the monocular images with the same parallax as when the opposite eye is occluded.

One can deduce indirectly from other types of experiments[2] dealing with rivalry and fusion that an actual fusion of the two monocular images is not likely to occur.

PROJECTION OF FOVEAL IMPRESSIONS

An object at the point of convergence of the two lines of sight produces images on corresponding points in the two foveas. These images of the two primary lines of sight are projected in the same direction from the center of projection and this direction can be assumed to be parallel to the bisector of the convergence angle formed by the primary lines of sight (See Figure 5A).

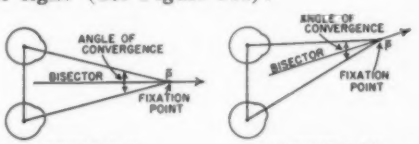

Fig. 5. The direction of projection of foveal impressions with symmetrical and asymmetrical convergence.

This can be proved in the case of symmetrical convergence by allowing a subject to converge his eyes on a distant object and walk toward it. A normal observer will follow a straight path toward the distant object. If the experiment is modified by putting prisms over the two eyes with the bases in opposite direction and the powers of the prisms equally distributed over the two eyes the subject will still walk straight toward the target. If a prism is placed over one eye the subject will deviate toward the apex of the prism by an amount equal to one-half the power of the prism.

Lesser[3] has called attention to this phenomenon and has made use of it in his recommended routine examination by carrying out the duction tests with the powers of the two prisms kept equal over the two eyes as the prism power is increased. If there is no apparent displacement of the object it means that the two eyes are converging to compensate the prisms, but if the object appears to move it means that the two eyes have lost fusion and that only one eye is fixating the target.

The theoretical implication of this finding is that our knowledge

of the direction in which the eyes are pointing is not based upon proprioceptive impulses from the extraocular muscles nor from other sensory impressions conveyed through the fifth nerve but is based upon an awareness of the amount of fixational innervation supplied to the eyes from the brain. This fits in very nicely with the notion that convergence movements are controlled by one center in the brain and fixational movements by another, with the awareness of the direction in which the bisector of the angle of convergence is pointed being based on fixational innervation and in no way influenced by the amount of convergence innervation. These facts are also consistent with Hering's basic law that each type of innervation is equally distributed to the two eyes.

It should be noted that the ability to walk toward a point looked at involves not only a knowledge of the position of the eye with respect to the orbit, but also the position of the head with respect to the body.

In the walking experiment described above bilaterality is prevented from becoming manifest, but if a person looks at a distant object through strong base-out prisms equally distributed over the two eyes and suddenly points at the object without sighting, the right arm will deviate to the left and the left arm to the right. Consequently there must be some unique connection between the right arm and right eye and between the left arm and left eye, which is independent of the perceived distance of an object.

The direction of the projection of foveal impressions is a learned affair as can be demonstrated by the capacity of a subject to adapt to a pair of prisms worn with the bases in the same direction before the two eyes. Errors in the direction of projection disappear after about three weeks.

No extensive investigations have been made of the direction of projection of foveal impressions in the case of asymmetrical convergence. Actually one can investigate this phase of the problem in the same manner as described above. The only modification required would be that of keeping the head turned while walking toward a distant object. The fact that the direction of foveal impressions is correctly perceived in asymmetrical convergence can be assumed from the fact that if a person attempts to keep his eyes glued on a distant point and moves his head from side to side there is no apparent displacement of the point in space. This stability of the point is remarkable when one appreciates the fact that it is dependent not only upon knowledge as to how much the eyes are turned but also knowledge of the amount that the head has turned. In the case of asymmetrical convergence it may be

assumed, therefore, that the image of the point of fixation is projected as in symmetrical convergence in a direction parallel to the bisector of the angle of convergence (See Figure 5B).

THE PROJECTION OF PERIPHERAL IMPRESSIONS

The image of a point on a secondary line of sight is projected in a direction from the center of projection which makes approximately the same angle with the x′ axis that the secondary line of sight makes with the primary line of sight.

Let us consider for the moment only those points which lie in the x, y plane, and assume that all of these points as seen by either eye are represented by points in the x′, y′ plane.

Experiments to test this postulate can be carried out to best advantage with one eye. If this postulate were not true, an object at which one is looking directly would appear to move when he moves his eyes to a new fixation point. Actually, in a well adapted normal subject neither of the two points appears to move and upon this fact and principle is based the degree of stability of objects in space which actually exists.

No matter how perfect the performance may appear to be in a monocular test like that described above, there are certain incongruities which cannot be detected by this test, but which can be demonstrated by partition experiments in which one attempts to place an object so that it will be midway between two others.

The existence of one type of incongruity can be deduced from the failure of the horopter to conform to a Vieth-Müller circle passing through the point of fixation and the centers of the entrance pupils of the eyes. In Figure 6 the point P_1 on the horopter suffers unequal

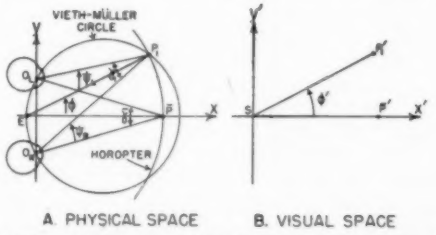

Fig. 6. Projection of the monocular images of a point on the horopter.

angular (ψ_L and ψ_R) displacement from the point of fixation measured at the entrance pupils. In spite of this, the dextrocular and sinistrocular images of P_1 are perceived as lying in the same direction. But in what direction? In order to deal with this problem it is necessary to define

two additional parameters of the point P_1, namely γ and ϕ. The parallax angle (γ) is the angle which the centers of the entrance pupils (O_L and O_R) subtend at the point P_1. Since the point E lies on the circle through P_1 and the centers of the two entrance pupils, the line P_1E bisects the angle γ. The angle ϕ that P_1E makes with the x axis is designated the azimuth angle of the point P_1. The angles ϕ and γ constitute the coordinates of a bipolar coordinate system having poles at the centers of the entrance pupils, O_L and O_R. Since

$$\phi = \frac{\psi_R + \psi_L}{2} , \tag{1}$$

it may be assumed that the point P'_1 in visual space lies at an angular distance ϕ' from the x' axis as measured at the center of projection S which is equal to ϕ.

The relationship of the parameters ϕ and γ to x and y are given by the following equations:

$$x = \frac{\cos 2\phi + \cos \gamma}{\sin \gamma} , \tag{2}$$

$$y = \frac{\sin 2\phi}{\sin \gamma} , \tag{3}$$

$$\text{Tan } 2\phi = \frac{2xy}{x^2 - y^2 + 1} , \tag{4}$$

and

$$\text{Tan } \gamma = \frac{2x}{x^2 + y^2 - 1} . \tag{5}$$

Curves in the x,y plane which represent loci of points having constant ϕ values are known as hyperbolae of Hillebrand and are given by the following equation:

$$-x^2 + y^2 + 2xy \cot 2\phi = 1 . \tag{6}$$

The equation for the Vieth-Müller circles which are the loci of points of constant γ value is as follows:

$$x^2 + y^2 - 2x \cot \gamma = 1. \tag{7}$$

A set of Vieth-Müller circles and Hillebrand hyperbolae for a given interpupillary distance is shown in Figure 7. As the distance from the midpoint of the interpupillary line increases, the Hillebrand hyperbolae become asymptotic to straight lines through the midpoint of the interpupillary line.

In using bipolar coordinates for the purpose of correlating physical and perceived space, I have merely followed the example set by Luneburg.[4] The system that I have used differs from his in that I have defined the poles as located at the centers of the entrance pupils which

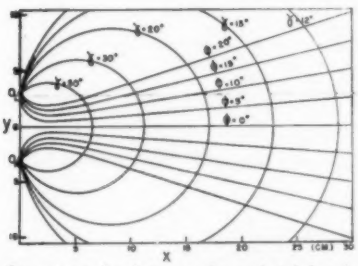

Fig. 7. Projection of the monocular images of a point lying between the eyes and the horopter and the relation of such a point in physical space to the point in visual space which is midway between the two monocular images.

shift with respect to the head every time the eyes change convergence or fixation.

In the case of a point P which falls in front of or behind the horopter, the dextrocular and sinistrocular images fall on non-corresponding points and are seen in different directions, the problem can be handled by attempting to locate the point P′ in perceived space which lies midway between the two monocular images. This may be arbitrarily called the point in perceived space which corresponds to P.

In Figure 8, $\overline{P}$ represents the point on which the primary lines of sight converge, and through which the horopter passes. The line PE bisects the angle γ and forms an angle ϕ with the x axis. The dextrocular and sinistrocular images of P will be projected in the same direction as the binocular images of P_R and P_L which are on the horopter, namely ϕ'_R and ϕ'_L. If $\phi'_R = \phi_R$ and $\phi'_L = \phi_L$, the line SP′ which makes an angle ϕ' with the x′ axis, which is equal to ϕ, bisects the angle $P'_RSP'_L$. However, since $\phi'_R = \phi_R$ and $\phi'_L = \phi_L$ are only approximations, the proposition that SP′ bisects $< P'_RSP'_L$ is also an approximation.

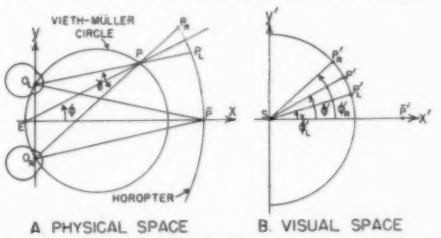

Fig. 8. Hyperbolæ of Hillebrand and Veith-Müller circles.

PERCEPTION OF THE DISTANCE OF OBJECTS ON THE X AXIS

Although stereopsis aids one in judging the relative distances of two or more objects, it does not give any information about the absolute

distance of objects. Other factors like geometrical perspective, monocular parallax, and awareness of accommodation and convergence *per se*, etc., must provide the cues for this.

Variations in binocular parallax for points at different distances along the x axis are correlated with varying degrees of retinal disparity (see Figure 9). The disparity is zero for the point of fixation ($\bar{P}$).

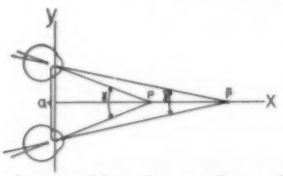

Fig. 9. The relationship between binocular parallax and perceived distance for a point on the x axis.

The disparity for any other point P on the x axis is proportional to the difference between the parallax (γ) for that point and the parallax ($\bar{\gamma}$) for the point of fixation; i.e.,

$$\text{Disparity} = k\ (\bar{\gamma} - \gamma)\ . \tag{8}$$

If $\bar{\rho}$ represents the perceived distance of $\bar{P}$ and ρ that of P, $(\rho - \bar{\rho})$ represents the perceived distance between P and $\bar{P}$. A fixed relationship between $(\gamma - \bar{\gamma})$ and $(\rho - \bar{\rho})$ would serve no useful purpose. As will be shown later

$$(\rho - \bar{\rho}) = -\frac{\bar{\rho}\ (\gamma - \bar{\gamma})}{\frac{a}{\bar{\rho}} + (\gamma - \bar{\gamma})}\ , \tag{9}$$

which means that $(\rho - \bar{\rho})$ is a function not only of the retinal disparity but also of the perceived distance of the point of fixation. The relation between perceived distance (ρ) of objects on the x axis and binocular parallax (γ) is learned through experience.

In order for a person to use his eyes most efficiently in manipulating near objects on the x axis with his hands, ρ must be equal to x. Since

$$x = \frac{a}{\gamma}\ \text{(approximately)}\ , \tag{10}$$

where a is the distance between the centers of the entrance pupils, it may be assumed that for $\bar{P}$

$$\frac{\bar{\gamma}}{a} = \frac{1}{\bar{\rho}}\ , \tag{11}$$

and that for P,

$$\frac{\gamma}{a} = \frac{1}{\rho_1} . \tag{12}$$

Subtracting (12) from (11)

$$\frac{1}{\bar{\rho}} - \frac{1}{\rho} = \frac{\bar{\gamma}}{a} - \frac{\gamma}{a} . \tag{13}$$

This reduces to

$$\frac{a\,(\rho - \bar{\rho})}{\rho\bar{\rho}} = -\,(\gamma - \bar{\gamma}) . \tag{14}$$

Combining these two equations we obtain Equation (9).

In spite of the fact that we learn to perceive space so that ρ will be equal to x for all points along the x axis, it is not always true that ρ is equal to x, but even when ρ is not equal to x Equation (9) must still hold.

Equation (13) can also be expressed in the form

$$\frac{1}{\rho} = \frac{\gamma}{a} + k , \tag{15}$$

where

$$k = \frac{1}{\bar{\rho}} - \frac{\bar{\gamma}}{a} . \tag{16}$$

The constant k will vary depending upon the factors that happen to be influencing the relation of perceived distance to actual distance at the moment or in a given field of view, but at a given moment k is a constant for various values of γ and ρ.

Another basic characteristic of stereoscopic vision is that one can line up a series of objects at different distances, and starting off with one which is relatively remote, he can converge on this starting point and then switch to one a little nearer and the perceived distance between the two will not have changed. If he continues to step off the distance from the more remote objects to an object close at hand in measuring worm fashion moving from object to object, he finally winds up with the near objects being perceived at approximately the correct distances, no matter how far off he may have been in judging the distance of the more remote objects.

This characteristic of stereoscopic vision can be deduced directly from Equation (13).

Let us take two points (P_1 and P_2) on the x axis and have the

eyes converge at P_1 which is the more remote of the two.

$$\frac{1}{\bar{\rho}_1} - \frac{1}{\rho_2} = \frac{1}{a}(\bar{\gamma}_1 - \gamma_2) = \frac{1}{\bar{x}} - \frac{1}{x_2} \tag{17}$$

or

$$\frac{1}{\rho_2} - \frac{1}{x_2} = \frac{1}{\bar{\rho}_1} - \frac{1}{\bar{x}_1} . \tag{18}$$

If now convergence is switched from P_1 to P_2

$$\frac{1}{\rho_1} - \frac{1}{x_1} = \frac{1}{\bar{\rho}_2} - \frac{1}{\bar{x}_2} . \tag{19}$$

If, however, the perceived distances (ρ_1 and ρ_2) are the same when the eyes converge on P_2 as when the eyes converge on P_1,

$$\frac{1}{\bar{\rho}_2} - \frac{1}{\bar{x}_2} = \frac{1}{\bar{\rho}_1} - \frac{1}{\bar{x}_1} = k . \tag{20}$$

Hence in stepping off the distance by converging in measuring worm fashion point by point from a remote object to a near object, while all these station points maintain fixed positions in perceived space, the relationship between $\bar{x}$ and $\bar{\rho}$ at each station point is given by the following equation:

$$\frac{1}{\bar{\rho}} = k + \frac{1}{\bar{x}} . \tag{21}$$

In Figure (10) $\bar{\rho}$ is plotted against $\bar{x}$ for different values of k. The

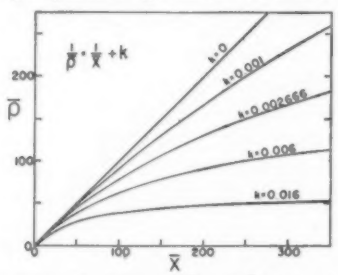

Fig. 10. The relationship between $\bar{\rho}$ and $\bar{x}$ for various values of k.

same curve that represents the relation between $\bar{\rho}$ and $\bar{x}$ also represents the relation between ρ and x for any value of $\bar{x}$ since Equation (16) is similar to Equation (21). The relationship between $\bar{\rho}$ and $\bar{x}$ is slightly affected by the variation in a with the fixation distance, and also by the fore and aft displacement of the interpupillary line, but these effects

are automatically compensated for since the perceived distances ρ_1 and ρ_2 remain the same when the eyes switch convergence from one to the other.

It should be noted that even with large errors in judging distant objects, little error is involved in judging near objects. In order to demonstrate for near objects that ρ is equal to x when ρ is based on stereoscopic cues, the following experiment was performed. A white cardboard (Figure 11A) and two pieces of lantern slide cover glasses (Figures 11B and 11C) were centered on the x axis with B in front of A and C in front of B, giving the appearance illustrated in Figure 11D when the eyes converge on the cross. The lines on A and C are

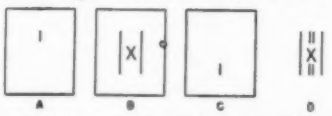

Fig. 11. A, B and C represent targets used in studying the relationship between binocular parallax and perceived distance at the near point. D represents the binocular impression of the combination of A, B and C when B is held in front of A and C in front of B.

seen doubled when the distances of A and C from B are large enough. A was kept constant at 40 cm. C was set at various distances and the subject attempted to set B so that it would fall midway between A and C. The results of a number of such settings are plotted in Figure 12.

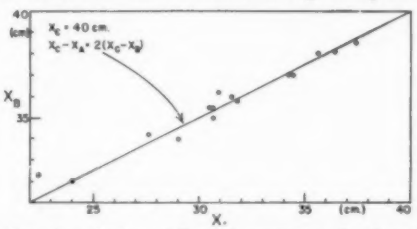

Fig. 12. Data showing the relation of B with respect to A when C is fixed at 40 cm.

Although there is lack of precision in this experiment, it is still obvious that the average result is that B does fall approximately midway between A and C when it is perceived that way.

It should also be noted in Figure 10 that when $k = O$, $\rho = x$ and this explains how it is possible for geometrical perspective and stereopsis to combine to yield a single, non-conflicting stable visual space.

It should also be noted from Equations (16) and (21) that even at the distance at which stereopsis is no longer effective in differentiating distances perceived, the distance $\bar{\rho}$ is still increasing as $\bar{x}$ increases.

It should also be noted that stereopsis does not impose any limit on perceived distance. Artificially one can arrange to throw images on the

two retinas which will be perceived stereoscopically as more remote than the stars or objects on the horizon.

However, it is not possible to increase the retinal disparity to make an object appear to lie behind an observer although the parallax γ is the same as for an object behind the eyes. This means that if an object of negative parallax is included in the presentation to the eyes, this object will be perceived as located at some finite distance in front of the eyes and all other perceived distances will be geared to this distance.

APPARENT DISTANCE OF OBJECTS OFF THE X AXIS IN THE X,Y PLANE

In attempting to relate the perceived distance of objects off the x axis to those on the x axis, one finds a certain amount of evidence for the proposition that all the objects in the x,y plane which lie on the horopter are perceived as having a constant ρ value.

On the basis of this assumption one can derive a general equation for perceived distance for any point P in the x,y plane.

In Figure 13A is shown the hyperbola of Hillebrand through P and the horopter through $\bar{P}$. These two curves intersect at the point P_1. The corresponding points in the x′y′ plane are shown in Figure 13B.

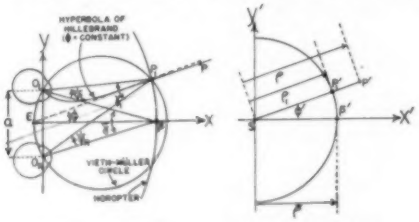

Fig. 13. The perceived distance of a point off the x axis.

The points P'_1 and P' lie on a straight line through the origin at an angle ϕ' from the x′ axis. Since according to assumption made above points lying on the horopter are perceived as lying at the same distance, P'_1 and $\bar{P}'$ lie on a circle centered at the origin S, and

$$\bar{\rho} = \rho_1 \quad . \tag{22}$$

It is logical to assume that the apparent distance (ρ) of a point off the x axis bears the same relation to retinal disparity as a point on the x axis, namely

$$\frac{1}{\rho} = \frac{1}{\rho_1} - \frac{\gamma_1}{a} + \frac{\gamma}{a} \quad . \tag{23}$$

As pointed out by Ogle[5] the horopter trace in the x,y plane can be described by the following equation:

$$\frac{1}{\text{Tan } \psi_L} - \frac{1}{\text{Tan } \psi_R} = H_1 \qquad (24)$$

where H_1 is a constant that varies with the distance of fixation and is defined as the Hering-Hillebrand deviation for the horopter.

Since the difference between ψ_R, ψ_L and ϕ is small it may be assumed that

$$\text{Tan } \psi_R \cdot \text{ Tan } \psi_L = \text{Tan}^2 \phi. \qquad (25)$$

Furthermore, for small values of ψ_L and ψ_R it may be assumed that

$$\text{Tan } \psi = \psi \text{ in radians,}$$

and hence

$$\text{Tan } \psi_R - \text{Tan } \psi_L = \psi_R - \psi_L = \bar{\gamma} - \gamma_1 \ . \qquad (26)$$

Therefore, Equation (24) reduces to

$$\bar{\gamma} - \gamma_1 = H_1 \text{ Tan}^2 \phi. \qquad (27)$$

If we substitute in Equation (23) the expressions for ρ_1 and γ_1 found in Equations (22) and (27),

$$\frac{1}{\rho} = \frac{1}{\bar{\rho}} - \frac{\bar{\gamma}}{a} + \frac{H_1 \text{ Tan}^2 \phi}{a} + \frac{\gamma}{a} \ . \qquad (28)$$

Since

$$\frac{1}{\bar{\rho}} - \frac{\bar{\gamma}}{a} = k \ , \qquad (29)$$

$$\frac{1}{\rho} = k + \frac{H_1 \text{ Tan}^2 \phi}{a} + \frac{\gamma}{a} \ . \qquad (30)$$

This equation and the equation,

$$\phi = \phi' \ , \qquad (31)$$

constitute the transformation equations by means of which one can locate the point P in physical space which corresponds to a given point P′ in perceived space, or vice versa.

THE METRIC OF VISUAL SPACE

For a given point of fixation and at a given moment during steady fixation of this point the visual space surrounding the projected image of this point is Euclidian.

If visual space is Euclidian the metric of visual space is as follows:

$$ds = dx'^2 + dy'^2 + dz'^2 \qquad (32)$$

where ds is the perceived distance between any two neighboring points. This means that any arrangement of lines and points in x′y′z′ space,

correctly represents an arrangement of lines and points as actually seen in visual space. Straight lines are seen straight, right angles are seen as such, parallel lines are seen parallel, etc.

The claim that visual space is Euclidian is based upon the observation that with fixation held constant on $\overline{P}$ in Figure 14 eight points

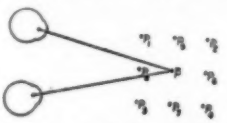

Fig. 14. Experimental arrangements for demonstrating that visual space is Euclidian.

(P_1, P_2, P_3, etc.) can be arranged to form a square. The perception of squareness is immediate and involves at one and the same moment all aspects of the concept of a square such as straight parallel opposite sides, right angle corners, and sides of equal length.

As Blumenfeld[6] points out, if one concentrates on getting the points arranged so that the pair of points P_1 and P_2 lie on a line parallel to the line on which P_3 and P_4 lie, he gets a different arrangement of the points than when he concentrates on getting P_1 and P_3 separated by the same distance as P_2 and P_4. Luneburg[4] has used this fact as a basis for his claim that visual space is not Euclidian.

However, in Blumenfeld's experiment the subjects were permitted to move their eyes as much as they liked, and their judgment involved comparison of space as perceived during different periods of fixation. It is likely, therefore, that Blumenfeld's finding may be traced to the changes in k which may occur from moment to moment and to the distortions of perceived space which occur with asymmetrical convergence.

In making the claim that visual space is Euclidian, it is not necessary to raise the question whether this concept of space is given a priori as a fixed, operating principle of one's mental machinery in the Kantian sense, or whether it is acquired through experience including one's formal training in geometry.

THE APPARENT FRONTAL PLANE THROUGH $\overline{P}$

The trace of the apparent frontal plane in the x′,y′ plane is a straight line through $\overline{P}$ normal to the x′ axis (Figure 15). P'_2 is any point on this line at an angular distance ϕ' from the x′ axis. The equation for the line is

$$\rho_2 = \frac{\bar{\rho}}{\cos \phi'} \quad . \tag{33}$$

This equation expressed in terms of $\bar{\rho}$ and ϕ', can be transformed

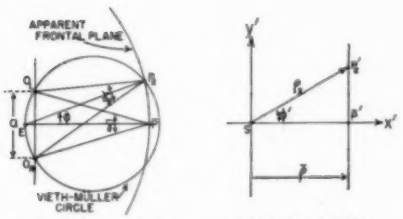

Fig. 15. The apparent frontal plane in visual and physical space.

by means of Equations (30) and (31) to terms of γ and ϕ, and the transformed equation is:

$$\bar{\gamma} - \gamma_2 = \text{Tan}^2\,\phi\ H_1 + \frac{a\ (\cos^2\phi)}{\bar{\rho}\ (1 + \cos\phi)}. \qquad (34)$$

Since it may be assumed that $\cos\phi = 1$ when ϕ is small,

$$\bar{\gamma} - \gamma_2 = \text{Tan}^2\,\phi\ H_1 + \frac{a}{2\bar{\rho}}. \qquad (35)$$

This represents the equation for the apparent frontal plane in the x,y plane (Figure 15).

The term, $H + a/2\rho$, may be designated H_2 and defined as the Hering Hillebrand deviation for the apparent frontal plane.

$$H_2 = H_1 + \frac{a}{2\bar{\rho}} = H_1 + \frac{\bar{\gamma} + ak}{2}. \qquad (36)$$

Ames, Ogle and Gliddon[7] have determined H_1 and H_2 for various values of $\bar{\gamma}$ and as is indicated in Figures 48, 49 and 50 of Reference (7) both H_2 and H_1 vary with γ and the relation between H_2, H_1 and $\bar{\gamma}$ expressed in Equation (36) is not far from the actual relation found, i.e., assuming that k is small. This can be taken as evidence of the approximate correctness of the assumptions which have been made in deriving Equation (36).

It should be noted from Equation (36) that the curvature of a perceived surface is a function of its perceived distance, and conversely perceived distance can be a function of perceived curvature. And this explains why it is possible to create an illusion of distance with a pair of paired prisms which produce asymmetrical distortion.[8]

It is possible to produce real conflicts between stereo cues and other cues of curvature and the perceived curvature will represent either a com-

promise or a complete suppression of one or more of the sets of cues.

It is conceivable that other cues than stereo cues might set the pace by establishing a plane or surface in perceived space and that the relative perceived distances of objects off the x axis will be based on this surface.

ASYMMETRICAL CONVERGENCE

Consideration of the problems associated with asymmetrical convergence has been avoided to keep the presentation as simple as possible. In asymmetrical convergence the problem is complicated by the fact that the difference in distance of the point of convergence from the two eyes causes the visual angle at one eye to be larger than that at the other. However, several factors help to compensate this effect and thus provide for a reasonable degree of agreement between physical and perceived space with asymmetrical convergence.[9, 10]

VISUAL SPACE WITH AN ELEVATED PLANE OF REGARD

Although experimental data are lacking so that there is no adequate basis for any theory, one can merely say that it is logical to propose that the problem is essentially the same with an elevated or depressed plane of regard as with a horizontal plane of regard. The x,y and x′,y′ planes rotate together around the base line connecting the centers of rotation of the two eyes.

THE x,z PLANE OF VISUAL SPACE

A different principle applies to the x,z plane than that which applies to the x,y plane. The basic fact that applies here is that a vertical line ($\overline{P}P_3$) normal to the x axis through the point of fixation $\overline{P}$ appears as a vertical straight line ($\overline{P}'P'_3$), i.e., if no cyclophoria is present (Figure 16). The images formed by the two eyes fall on the vertical meridians of the two retinae. This means that the trace of the horopter in the x,z plane is a vertical straight line. Furthermore, since the stereoscopic impression is that of a vertical line in the x′,z′ plane normal to x′

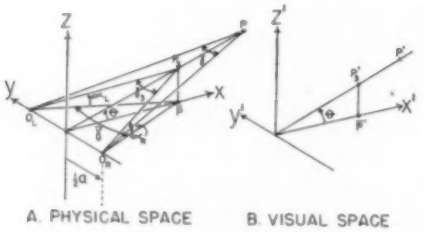

Fig. 16. Perception of the direction and distance of a point in the x, z plane.

axis, this means that the horopter is tangent to the apparent frontal plane in x,z plane.

An equation for the apparent distance (ρ) of a point P in the x,z plane in front of or behind the horopter can be derived as follows: In Figure 16A, P represents any point in the x,z plane. The straight line through this point and the origin crosses the x axis at an angle θ and intersects the horopter at P'_2. Figure 16B shows the corresponding points in visual space.

The basic equation for the perceived distance of P is as follows:

$$\frac{1}{\rho} = \frac{1}{\rho_3} - \frac{\gamma_3}{a} + \frac{\gamma}{a} . \tag{37}$$

But since,

$$\frac{\bar{\rho}}{\rho_3} = \cos \theta' , \tag{38}$$

and

$$\frac{\gamma_1}{\bar{\gamma}} = \cos \theta , \tag{39}$$

$$\frac{1}{\rho} = \frac{\cos \theta'}{\bar{\rho}} - \frac{\bar{\gamma} \cos \theta}{a} + \frac{\gamma}{a} . \tag{40}$$

If it is true for the x,z plane as for the x,y plane that perceived angular size is approximately equal to the angle subtended at the entrance pupil of each eye, then

$$\tan \theta' = \tan \alpha_R = \tan \theta \cdot \cos (\bar{\gamma}/2) . \tag{41}$$

THE RELATION OF PERCEIVED SIZE TO PERCEIVED DISTANCE

To illustrate the problem let us consider a small disk centered on the x axis in a plane normal to the x axis (Figure 17). In physical space the diameter is the same in all meridians but in visual space it is longer in the vertical meridian than in the horizontal.

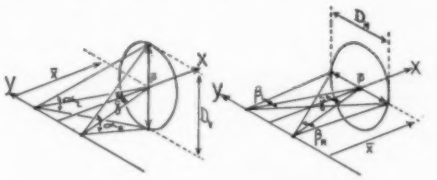

Fig. 17. The relation of perceived distance and perceived size in the horizontal and vertical meridians.

Assuming that the perceived angular size is equal to the angle subtended at the entrance pupil of each eye, we find in the vertical meridian, that

$$\alpha' = \alpha_R = \alpha_L = \frac{D_V \cos (\bar{\gamma}/2)}{\bar{x}} \quad . \tag{42}$$

In the horizontal meridian

$$\beta' = \beta_R = \beta_L = \frac{D_H \cos^2 (\bar{\gamma}/2)}{\bar{x}} \quad . \tag{43}$$

It should be noted that

$$\frac{\alpha'}{\beta'} = \frac{1}{\cos (\gamma/2)} \quad . \tag{44}$$

The ratio of $\frac{\alpha'}{\beta'}$ decreases as the distance of the disk increases. Even at 40 cm. the ratio is as small as 1.0028 when $\alpha = 60$ mm., and at this distance as well as greater distances, it may be assumed that

$$\alpha' = \beta' = \frac{D_H}{\bar{x}} = \frac{D_V}{\bar{x}} \quad . \tag{45}$$

Since most of the problems involving the relation between perceived size and distance apply to much greater distances than 40 cm. the general equation may be stated as follows:

$$\frac{D'}{\rho} = \frac{D}{\bar{x}} \quad . \tag{46}$$

Equation (46) applies not only to situations, where stereopsis is the primary factor in determining perceived distances, but even in monocular vision and at distances greater than those which can be differentiated by stereo cues. For example, the greater apparent size of the moon at the horizon as compared to the zenith can be attributed to the greater apparent distance at the horizon.

This means that if an object of given angular size is presented to an observer, the perceived size must vary with the perceived distance. On the other hand, if the object is one with which the observer is familiar, his knowledge of the actual size may influence the perceived distance.

VISUAL SPACE IN THE QUADRANTS FORMED BY THE x′,y′ AND x′,z′ PLANE

Additional data should be acquired before attempting to extend the

basic principles which apply in the x,z and x,y plane to the quadrants between these planes. Little is known for example about the shape of the horopter in these quadrants, and there is little basis for conjecturing about it.

CYCLOPHORIA AND MERIDIONAL DIFFERENCES OF MAGNIFICATION

It has been assumed that no cyclophoria exists and that points in the x,y plane seen by either eye are perceived as lying in the x′,y′ plane.

Attention is called to the problems presented by cyclophoria and meridional differences of magnification primarily to acknowledge their existence, but it may also be added that no harm is done by deferring consideration of these problems while formulating the more basic problems of visual perception of space.

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ABSTRACTS

VISION IN INDUSTRY. H. S. Kuhn. Transactions of the American Academy of Ophthalmology and Otology. Sept.-Oct. 1947.

This paper represents the material presented in a lecture given at the Yale University Institute of Occupational Medicine and includes a brief discussion of 11 individual units which comprise an industrial eye program. These units are: I. Medical and Surgical Care of Eye Injuries. II. Toxic Hazards. III. Eye Hazards and Eye Protection Equipment. IV. Close Cooperation with Management. V. A Thorough Knowledge of Job Operations. VI. Choice of Type of Pre-employment Visual Testing. VII. Understanding of Illumination and Color in Industry. VIII. Educational Projects. IX. The Private Office vs. the Plant Itself. X. Medico-Legal Angles. XI. Constant Search for Knowledge.

Of special interest are Dr. Kuhn's favorable comments on the cooperation of optometrists in doing the refractive tests. She states: "The experience in the war where optometrists did the major portion of the refracting and the experience in many industries in the country during the war where optometrists were on the staff and bore the brunt of the refracting program indicated the need for this type of cooperative effort."

R. E. B.

VISUAL FATIGUE*

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The subject of fatigue has been investigated from many angles and by many research workers. However, the results of all investigations have failed to give us a clear and concise definition of the meaning of the word "fatigue." The anatomist attempts to define fatigue on the basis of energy output and the loss of tissue function. His views are shared by the physiologist. The psychologist goes further than these two and adds to his concept the total organism's attitude and the behavior towards situations. He, accordingly, broadens his definition to include these two viewpoints. As a result, it becomes impossible to formulate a simple definition of fatigue. It helps in a small way to refer to fatigue as a state or condition just as the word "sickness" helps in a small way towards the comprehension of that very complex subject. As in the use of the term sickness, which does not define the person's specific kind or type of disability, so in the use of the term fatigue in its broad sense, there is no explanation or definition of the particular condition that is present in the individual.

Bartley and Chute, in their book, "Fatigue and Impairment in Man," after reviewing many definitions of the subject, finally solve the problem by identifying fatigue with the following descriptions of what they say "it is and is not."

1. Fatigue and impairment are not identical. When both exist at once, they can be separated.
2. Fatigue is not to be measured by measuring impairment.
3. Unlike impairment, fatigue is always directly experienced; i.e., it is an actual experience.
4. Fatigue is a part of the individual's stance with reference to activity.
5. Fatigue is a manifestation of personal continuity.
6. Fatigue is personal.
7. Fatigue is an outcome of conflict.
8. Fatigue is not to be confused with boredom.
9. Fatigue is cumulative.
10. Fatigue's onset and recovery may be sudden.
11. The concept of fatigue pertains to organization.
12. Fatigue does not crucially depend upon energy expenditure.
13. Fatigue is never specific to a given body member.

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*Read before the New Jersey Chapter, American Academy of Optometry, Trenton, New Jersey, as one of a series of lectures on occupational optometry. For publication in the November, 1950, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

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14. Fatigue is not to be defined or analyzed in terms of its supposed origins, or on the basis of function involved.

Thus, it can be seen that a definition of fatigue on the basis of work output, or in its relation to any other external situation of the individual, does not give us a complete picture of the subject. As far as the attitude of the individual is concerned, he is just as tired from mental work as he is from physical exertion. Therefore, there is very little difference in the fatigue produced by these two broad categories which take in practically all of man's activities.

Some investigators separate the definitions of fatigue and impairment by using the former in the broad sense of the person's feelings and attitude while using the latter strictly in the sense of those measurements of tissue changes found by the physiologist and biochemist. This concept, then, takes changes in muscle chemistry out of the realm of fatigue itself but does not preclude them from serving as one of the basic causes of fatigue. Therefore, in order to understand one of the major factors producing fatigue, it is necessary to look into the subject of myology. Here, a brief review of the normal muscle functions will help us to understand some of the physical causes of fatigue.

Muscles, in order to function normally, must receive three groups of nerve impulses. The first group is efferent and continuous. These impulses give the muscle its normal tone and produce a mild, constant state of contraction. The muscle tone varies with the state of health of the individual and also with the amount of use or training received by the particular group of muscles under consideration. The muscles are never relieved of this group of impulses except in the case of paralysis or death.

The second group of impulses are the voluntary motor impulses. These produce motion and work. It is the output measured from this type of innervation which is used in determining the state of fatigue or impairment of a particular system of muscles. This second group of impulses is made use of in the stimulation of muscles by the will of the individual. It lasts only so long as he wishes. In normal neuromuscular activity, it requires about one-tenth of a second for a muscle to receive an impulse to contract, and then to relax. In this process, the muscles usually contract about one-sixteenth of their length. It can be seen, therefore, that the smaller muscles, because of the shorter distances of their contractions, are capable of more rapid vibrations than the larger muscles. The muscles in the larynx, which produce the voice, for example, vibrate about 25 times per second. This is the most rapid muscle vibration in man. The muscles in the wings of a fly vibrate

as many as 300 times a second. From these figures, it must be evident that the voluntary motor impulses are largely responsible for neuro-muscular fatigue.

The third group of impulses to reach the muscles are afferent. These come from the spindle cells and keep us informed of movement and general muscle "feel." The spindle cells make up the proprioceptive nervous system. The awareness produced by this neural mechanism is called "kinesthetic imagery." A lack of this muscle sense is referred to as "ataxy."

These groups of impulses contribute the total innervation necessary for all normal muscle functions. The operation of these impulses, however, is made complex by the introduction of such factors as reflexes, reciprocal innervation, coordination and willful motion. In the operation of all these factors, chemical changes take place that affect the musculature in two ways: first, by the consumption of contractile material within the muscle: and secondly, by the accumulation of the by-products of the contractile process, which is mostly lactic acid. These two chemical changes utilize glycogen and oxygen and are, therefore, responsible for the consumption of a large portion of our food intake. The breakdown of glycogen or animal starch into lactic acid is largely a reversible chemical process, four-fifths of the lactic acid being converted back into glycogen and one-fifth of it being carried away as the waste product, carbon dioxide, in the blood stream.

The weakest point in the neuro-muscular hook-up is in the motor end plates. These are the junctions between the nerve endings and the muscle, itself. Not every muscle fibril receives a nerve ending. It is not necessary for every fibril to be innervated because when a contractile impulse is started in a muscle bundle the entire group of fibers in that bundle go on to complete contraction. It is here that the "all or none" principle in muscle physiology is particularly applicable. Either all of the fibrils of a single muscle bundle contract or else, if the stimulation is of insufficient strength for this to occur, no contraction results. When a muscle is contracted too frequently and insufficient rest periods are provided to enable its metabolic processes to get back to a normal state, the accumulation of the chemical waste products tends to insulate the end plates so that impulses existing in the nerves of the muscles are unable to produce further contractions. This is nature's protective mechanism against injury to the organism by over-use and a means of preventing the chemical changes in the muscles from reaching a stage where they could cause actual injury to the organism. The first place, then, where we may encounter physical fatigue is in the motor end plates of the muscles.

The second reason for the production of muscular fatigue lies in the muscle chemistry, itself. The consumption of glycogen and the subsequent production of lactic acid, together with the failure of the oxygen supply to keep up with the demands of the contractile processes, produce a metabolic type of fatigue or impairment, if one wishes to use the latter term. Obviously, the amount of work that can be performed by a muscle will depend on the extent and constancy of its supply of glycogen and oxygen. Therefore, in dealing with fatigue it is necessary to make certain that these two factors receive full consideration. An ample supply of food and a proper ventilation of working quarters are essential for preventing fatigue in the worker as a result of improper muscle metabolism.

The third weak point in the neuro-muscular picture is the possibility of a breakdown along the neural pathways at the synaptical connections. Actually there cannot be fatigue within a neurone. A single nerve cell is capable of transmitting over 1,000 impulses per second with complete recovery after each impulse. Since the fastest response that a human muscle is capable of giving is 25 vibrations per second, it can be seen that nerve tissue never reaches the point of tissue impairment. However, a synaptical insulation may develop as a result of the accumulation of muscular waste products throughout the entire system. It is thought that sleep is induced by such a process. Undoubtedly a collapse occurs if the energy output is carried to extreme. The synapses in the basal ganglia are believed to provide the anatomical location for the induction of sleep. Therefore, in cases of fatigue resulting from synaptical breakdown, general rest is the only recuperative measure able to bring this area back to normal functioning.

From the above discussion, it can be seen that if we could prevent the impairment of motor end plates, prevent the accumulation of the chemical waste products of muscle metabolism, and prevent the blocking of neural impulses at the synaptical connections, we could then stop or at least delay, the onset of fatigue indefinitely. However, no drug has been found that can in any way lessen or even postpone the operation of any one of these three processes. Consequently, we are limited to the use of simple rest and relaxation for producing normal tissue repair. It has been shown, experimentally, that if the blood of a completely exhausted dog is transfused to a dog that has just had a complete rest, the rested dog, who should be fresh and active, will act very tired and show evidence of fatigue. Likewise, if the blood of a fully rested dog is transfused into a fatigued dog, the fatigued dog will now be fresh and active again. These experiments demonstrate that fatigue

products do exist in the blood and that there is no quick way of removing them. Perhaps it is better so, because damage could be wrought if it were possible to work a muscle beyond the point of motor end plate insulation.

As can be seen from Bartley and Chute's 14-point description of fatigue, the psychological aspect of fatigue must also be considered. Here, there exist no obvious methods of measurement for the entire individual. Therefore, each person, according to his individual interest, measures fatigue by some performance that applies to his type of work or interest. Hence, a manufacturer measures the fatigue by the work output, a military leader by combat performance, a research director by the amount of "paper work" produced, and so on. The subjective nature of fatigue is so great that in its final analysis we can depend only on the nature of the responses of the individual to his environment. However, in addition to his environment, the mental state of the individual at any given time is both a direct cause and a contributing factor to his feeling of fatigue. Boredom, monotony, frustration, conflict and many other mental states, although not directly identified with fatigue, are very definitely the contributing causes of fatigue. Rhythmic repetition of external stimuli, whether auditory, visual or tactile, induces a state of mild hypnosis and, therefore, contributes to the occurrence of fatigue in industry. Much more could be said about the psychological phases of fatigue, but such a discussion is beyond the scope of this article. Industry solves the psychological problems of fatigue by instituting periodic rest periods and by organizing sporting teams, glee clubs, dances, etc., for the workers.

As previously stated, it is incorrect to speak of sectional fatigue in the body, such as an arm fatigue, a leg fatigue, a visual fatigue, etc. When a person is tired, his reaction is a total reaction; yet, at the same time, it may be true that some member of the body is setting up the primary cause for this total feeling of fatigue. The eyes have been regarded as the most important organs for the inception of fatigue. To determine whether this is true, we should study the visual function in all its aspects in order to find out what factors in the environment or in the visual apparatus, *per se*, contribute directly or indirectly to ocular tiredness. First, let us consider the retina. Much has been written about fatigue in this particular part of the eye, but in the Duke-Elder's "Textbook of Ophthalmology," Volume 1, we find the following statement:

> From time to time many phenomena have been described as indicative of processes of fatigue in the retina. Following Parsons (1924-1927) I prefer not to use the term, since, with its usual physiological connotation, it gives a wrong impression of the

mechanism involved. There is no evidence that fatigue in the usual sense of the word—as applied for instance to muscular activity—ever occurs in the retina in ordinary circumstances. If it does, it is too transient to be noted. The reversibility of the chemical changes in the retina seems able to cope with all normal activity, and the eyes may be exposed to light and continue to record impressions indefinitely without any functional failure; as when they are employed for many hours in continued and concentrated activity (as, for example, in reading, when something of the order of 80 impressions are recorded per second). Any evidence of fatigue in vision is due to a functional failure of the ciliary muscle, a failure in the coordination of the extra-ocular muscles, or in the higher processes of attention and interest. Thus the lowered visual acuity which is readily demonstrable on continued observation (Mosso, 1915; Breton, 1920; Jackson, 1921; and others) is due to fatigue in mental or even general bodily processes, and the gradual depression of a sensation under the influence of a continued stimulus is an example of induction. It is true that with pathological intensities of stimulation, pathological effects result (sun-blindness, etc.), but these occupy a different category. On the other hand, any changes which may be produced by stimuli within physiological limits are explicable to the physiological process of induction; of retinal fatigue there seems to be no evidence.

If we accept the considered opinions of Duke-Elder and others that the retina itself is unlikely to be a victim of fatigue, then we must examine further into the visual mechanism for an explanation of visual fatigue. Our next most logical step would be to examine the musculature of the eyes. Here, fatigue or impairment of function exists in all its physical aspects—in the ciliary muscle, in the extra-ocular muscles and in the orbital muscles. The symptoms of this ocular myologic fatigue are dull headaches, heaviness of the lids, drowsiness, pain in the eyeball, and all the asthenopias of ametropes.

Faulty illumination stands out as the most common external environmental cause of visual fatigue. There seems to be little agreement among investigators as to the amount of illumination that is essential for any particular task. This state of affairs is mainly the result of the high adaptability of the visual mechanism to varying strengths of illumination. Some workers find that reading can be carried on indefinitely at an illumination level of less than 10-foot candles. Carmichael and Dearborn, in their book, "Reading and Visual Fatigue," used 16-foot candles for their experiments and found that after six hours of continual reading, no appreciable fatigue could be demonstrated or elicited from the subjects. Most of the investigations in illumination have been along the lines of finding the minimal need for particular tasks with the idea that there is no upper limit because there can be no such thing as too much light. As yet the task of setting these minimal standards is far from complete. For the present the most that can be said is that if a person sees his work well, he can perform it.

There are also some other recommendations that have been made concerning illumination in industry. These recommendations pertain to the relationship between the amount of light at the point of work compared to the amount of light in the rest of the room. An ideally

lighted room for working would have the following qualifications: First of all, sufficient light for the performance of the task in hand: and secondly, a variation of not more than three per cent in light intensities for all areas within the worker's field of vision. The first requirement may be achieved easily, while the second one is an ideal to which we should strive. In general, a variation of 10 per cent is considered good. Practically, the illumination of the rest of a work room should never be less than 50 per cent of the illumination in the worker's immediate area. This condition can be achieved in most cases.

Contrast is another important factor in the consideration of fatigue, because it determines the ease or difficulty experienced in seeing a piece of work. By the use of contrasting colored paints on machines, on jigs and on instruments, the highest visual contrast can be achieved for the worker's ease of vision. This should be done especially where the work consists of a repetition of a process over a long period of time. Glare, too, should be considered here because the reduction of glare to a minimum will lessen the tendency of the worker to experience fatigue. Surface glare can be reduced by proper treatment with paints. Illumination glare can be reduced by the use of shades or screens, or by other means.

Studies in visual fatigue have been carried out in a number of ways such as by measuring the pupillary size at various times of the day; by measuring the blink rate and by correlating this with visual tiredness; by measuring the amount of accommodation after prolonged use of the eyes; by the flicker test, which is the measurement of the rate of flash necessary to make a discontinuous light begin to appear continuous to the observer; by varying the illumination and noting its effect on the heart rate; and by many other sensory measures. However, no important generalizations of universal application have come out of these studies.

The one outstanding result obtained in these studies which may be used for an interpretation of the meaning of visual fatigue is the verification of a well-known principle in physiology. This involves the observation that fatigue sets in more quickly in the performance of an ocular task which requires a large change in accommodation and in motor movements than in the performance of a task which requires long continued but only small changes in the ocular musculature. This means that fatigue sets in much sooner if a task requires the constant alternation of far and near accommodation or constant adjustment of the pupillary size because of unequal illumination. The onset of ocular fatigue is greatly retarded if the worker's visual performance is carried out at a constant, fixed distance in a field of illumination which is relatively even.

The following quotation from Louis Resnick's "Eye Hazards in Industry," will serve as an appropriate conclusion to this brief discussion of ocular fatigue.

> Fatigue of workers is one of the principal causes of industrial accidents and of production losses generally. Among the factors influencing fatigue are the type of work, the length of the working period, environmental conditions of work and the state of health of the worker. Monotonous operations, performed over long periods without interruption, are usually conducive to fatigue. Bad ventilation, poor illumination and excessive noise also bring about undue fatigue. In many operations, however, the greatest single factor influencing fatigue is eye strain.
>
> Eye strain, the result of excessive accommodation, can be caused by defective vision, by poor illumination and by the constant requirements of fine, or close, eye work. Persons with normal vision may suffer from eye strain quite as much as those with defective vision.

Obviously, optometry's best contribution to the problem of visual fatigue in industry is the performance of a competent and thorough ocular examination so as to provide the worker with the greatest visual efficiency. This service, together with consultation services on individual operations, illumination, contrast, the prescribing of goggles and special aids and a consideration of the phases of a worker's visual tasks go to make up optometry's very important contribution to the prevention of visual fatigue in industry.

ABSTRACTS

A NOTE ON THE PHOTO-PUPIL REFLEX. Jules de Launey. Journal of the Optical Society of America. 39.5.364. 1949.

A preliminary study was made of the variation of pupil diameter with illumination of the retina. The experimental method involved the production of a specified stimulus on the retina and a photographic procedure to measure pupil diameter after the eye had had sufficient adaptation time. The stimulus consisted of a 2° circular disk of white light falling either on the fovea or 8° temporally to the fovea. The eye was dark adapted before each stimulus exposure. After 10 or more seconds, an instantaneous flash photograph was taken, and measurements of pupil diameter obtained from a 2X enlargement.

Great care had to be exercised to rule out such factors as mechanical influences, psychic influences, ciliospinal reflex, orbicular reflex, etc. The results showed quite a dispersion in pupil diameter for the same eye under similar conditions at varying times.

The author concludes that the photo-pupil reflex is confined to the photopic range of illumination. He proposes the hypothesis that the photo-pupil reflex is essentially initiated by cone response. Due to the fact that the author is at present engaged in another field of research, he makes various suggestions for further investigation. For example, it would be interesting to test his hypothesis by investigating the photo-pupil reflex in a totally color-blind subject, particularly one who has a central scotoma and presumably possesses only rod vision.

BERNARD ROSETT

AN ANALYSIS OF INHOMOGENEITY OF MYOPIA IN ADULTS*

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There are certain characteristics of the frequency distribution for total refractive state which must be taken into account in any biological or physiological hypothesis of myopia causation. The lack of normality of the curve, its skew or asymmetry, and leptokurtosis or excessive peakedness are among these characteristics which must be considered in any successful hypothesis. The suggestion that the lack of normality is due to the presence of more than one overlapping distribution is by no means new. Tron (1940) felt that his data indicated the presence of two distributions, "a curve of normal variability for axial length and for all refractions except high myopia and another for axial length in high myopia." He suggested that if eyes with more than 6.00 D. of myopia were omitted from the calculations, the frequency distribution for *computed axial length* approximated a normal curve. More recently, Stansbury (1948) has urged a new classification based upon two types of myopia: "(1) Primary, or physiological, myopia; and (2) secondary, or pathological, myopia." He reviews the suggestions of many former workers for a dual classification and cites numerous authors who, in the past, have held a dual category hypothesis.

Titoff (1937) investigated the refractive state of 1,000 adult patients in the gynecological, neurological, and surgical services of a European hospital. He stated that the frequency curve was both skewed and leptokurtic and that, even when myopes of over 6.00 D. had been excluded, the curve was still asymmetrical and leptokurtic.

The problem of separating two or more overlapping normal distributions mathematically is extremely difficult. While it seems very probable that there is more than one frequency distribution, evidence for only two types of myopia is by no means conclusive. Titoff's finding that skew and kurtosis are present even after excluding all myopes above 6.00 D. would seem to indicate that this arbitrary distinction, although simple, is not adequate to explain the facts.

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The present paper represents an analysis of the records of 562 myopic eyes selected from the files of the clinic of the Los Angeles College of Optometry.

SELECTION OF CASES

If refractive state data are to be interpreted as representative of the general population, certain precautions must be taken. Cases seen in private practice or clinics are not a random sampling of the population, but rather represent a group who have had some reason to seek advice about their eyes. It should be noted in passing that Titoff's method of selecting—that of choosing patients in hospital wards other than the ophthalmological—represents one good way of obtaining a random sample. Another method, although not hitherto utilized is the use of myopes only. Persons essentially emmetropic would not be as likely to visit an eye clinic as those having refractive errors, but there is no reason to believe that high myopes would be more likely to seek eye care than those having a moderate, but nevertheless significant, degree of the anomaly. In the present study, only cases having 1.00 D. or more of myopia were chosen.

Another basis for limiting the sampling range is the evidence for an increase in myopia during and just following puberty as well as for changes in refraction in some individuals after the age of 50. For this reason the data in the present study were limited to patients between the ages of 18 and 50.

Except for these two characteristics, cases were selected at random in the following manner: The clinic cards from the alphabetically arranged master file were systematically examined. All eyes exhibiting an equivalent spherical power for the subjective refraction of 1.00 D. or more of myopia were selected; those whose ages were below 18 or greater than 50 were rejected, leaving as the basic data 562 eyes. It is felt that this group represents a sampling within the curtailed age and refractive range which is as nearly random as the use of clinic data makes possible.

METHODS OF ANALYSIS

Since the mathematical problem is, as has been stated, an exceedingly difficult one and since it is not the intention of the author at this time definitely to state the exact limits for the types of myopia to be discussed, rough methods of statistical analysis have been used. In the separation of two normal curves from a single distribution it is necessary (Court, 1949) to (a) assume a value for the means of the two distributions, or (b) assume a value for the standard deviations of

the two distributions, or (c) calculate the fifth moment about the mean and solve a ninth degree equation. Furthermore, in any of the above conditions it is necessary to know the mean, standard deviation and either the third or fourth moment of the total distribution—data not available in the present study since only a portion of the total distribution curve was analyzed. In the present analysis it was necessary to assume a value for the mean of the first curve. The value chosen—one which it is felt closely approximates the true value—is 0.50 D. of hyperopia. It is stressed that this assumption had to be made because of the nature of the present analysis.

One of the properties of the normal curve is the linear relationship between the logarithms of the ordinates and the square of the deviations from the mean. The present analysis consisted essentially of the following steps:

(a) The values for the degree of myopia were converted by the effectivity formula to degrees of myopia at the principal plane of the eye, assumed in this case to be 15 mm. behind the spectacle plane.

(b) Frequency distributions for the various degrees of myopia were set up separately for the 291 eyes of male patients and 271 eyes of female patients.

(c) The logarithm of each frequency was plotted against the deviation from the assumed mean of +0.50 D. This curve was found to be linear for the first five or six points, after which a distinct change of slope was noted. A line was fitted to these points closest to the mean.

(d) A normal curve corresponding to this linear function was then plotted. This represents the α group in the following discussion.

(e) Where this curve overlapped the empirically determined raw frequency distribution, the ordinate values for the α curve were subtracted from the ordinate values of the empirical data, leaving a residual curve.

(f) The mode of the remaining distribution was noted and was assumed to be the mean for the next, or β, curve. This was then treated in a manner similar to that described above, i.e., the log of each frequency was plotted against the squared deviations from the new, assumed mean.

(g) Again it was found that the relationship was linear for a number of points closest to the assumed mean. The second normal curve, β, was fitted, and the number of cases remain-

ing was placed in the third, or γ, group. The number of cases beyond this point is too few to justify further analysis.

RESULTS

The results of the analysis are presented in graphical form in Figures 1 and 2*. The solid points represent the empirical data expressed as frequencies and smoothed by threes. The curves sketched in represent the two curves which have been fitted, by inspection, those cases exhibiting more myopia than the β group are considered to lie in the τ group. It will be noted that in the data for the females the α curve was fitted essentially for the first five points, while in the data for the males the α curve was fitted for the first seven points.

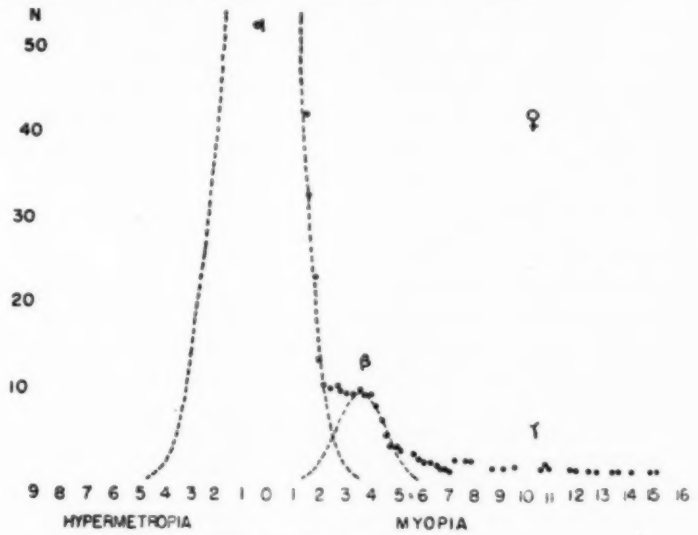

Fig. 1. Curve for females.

CONCLUSIONS

The presence of a plateau, or hump, in the distribution of empirical data at 3.00 and 4.00 D. of myopia (especially in the data for the females) suggests that the data cannot be fitted by a unimodal fre-

*Refractive state may be expressed either in terms of the correction lens, or in terms of the relative refractive power of the globe. A 1.00 D. myope would require a —1.00 D. lens and would have a refractive power 1.00 D. greater than an emmetrope. In the older studies, especially in those of the German authors, refractive power was considered and, hence, myopia was plotted to the right, hyperopia to the left. In the figures here presented this scheme was followed in order to allow ready comparison with the data of other authors.

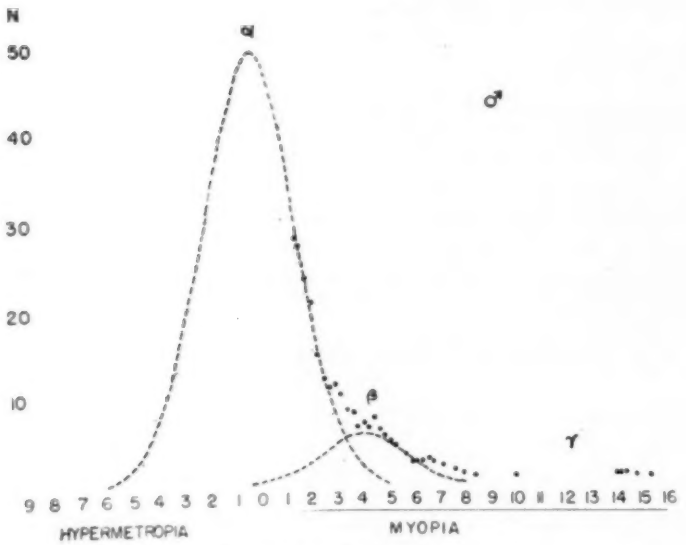

Fig. 2. Curve for males.

quency distribution, either normal or skewed. Titoff's statement, that even after the exclusion of myopes above 6.00 D. the distribution is not normal, seems to be confirmed. Three possibilities now remain:

(a) The distribution may be fitted by two overlapping skewed curves.

(b) The central portion of the distribution can be fitted by a normal curve (α) and the remaining cases of myopia can be fitted by a skewed curve.

(c) The central portion of the distribution can be fitted by a normal curve (α), and the remaining cases can be fitted by a second normal curve (β), leaving a series of cases (γ) which may or may not be normally distributed, the number in the present sample being too small to permit determination of the form of the curve.

The third possibility is the one which has been followed in fitting the curves in Figures 1 and 2. The first two possibilities entail the use of one or more non-normal distributions. It should be clear that while normal distributions are the rule in biological data, there is nothing compulsory about such distributions. The present author prefers a hypothesis based upon the third possibility, i.e., one based upon the

postulation of a series of normal curves. This preference does not, however, rule out hypotheses based upon the other two possibilities. Before discussing the author's hypothesis the other two possibilities should be considered.

The presence of two skewed distributions, while a possibility, has not been seriously considered in the past, probably because most biological data are normally distributed. If such a hypothesis is advanced, some explanation of the skew (possibly the scale not being in conformity with a biological variable) should be offered. Actually, refractive state bears a direct relationship to axial length, and such a hypothesis, while possible, would be difficult to defend.

The presence of one normal distribution and one skewed distribution is essentially the basis for the most widely held hypothesis at present. The statement above differs from Tron's hypothesis only in that it substitutes a pair of overlapping distributions for a point of sharp demarcation—at —6.00 D. the area of overlap being between 0.00 and 5.00 D. of myopia. The second distribution in such a hypothesis would be skewed toward higher myopia. The difficulty in defending such a hypothesis is the difficulty in defending the initial assumption, i.e., that of normality of the major curve, (α). Tron's reason for a point of demarcation at —6.00 D. was that the α curve was then normal. One might ask why the α curve should be normally distributed, and the only answer is that this is in conformity with other biological data. But if this is the answer, then how can one defend the lack of normality of the cases beyond 6.00 D. of myopia? Seemingly, such a theory lacks consistency, and this is the major reason for the author's preference for the third possibility. If a reason exists for fitting the central portion of the distribution to a normal curve, then the same reason should necessitate the postulation of normality for the remaining cases. If, on the other hand, there is a reason for lack of normality in the β curve (such as scale), then Tron's original assumption of normality of the α curve is not defensible.

Of the three possibilities, that of two skewed curves, a normal and a skewed, and a series of normal curves, the last is the most attractive to the present author at the present time. The most widely held theory, that of a normal and a skewed curve seems to suffer from either a lack of defense of assumption of normality for the α curve, or a lack of explanation of the skewed β portion. The possibility of two skewed curves is more attractive, but in the absence of any explanation for a lack of normality the third possibility, that of a series of normal curves, seems the most easily defended. The following hypothesis is based upon

this possibility, but it should be stressed that the assumptions are not necessarily valid. This hypothesis seems merely to be the best at the present time.

On the basis of these data certain speculations may be made and a tentative hypothesis advanced—again stressing the fact that while this hypothesis is by no means proven, it may well serve as a starting point for future investigations. This hypothesis may be stated as follows:

(a) The main body of the frequency distribution, at least as represented by the limb of the myopia curve above 1.00 D., cannot be represented by a single regular distribution. It may be represented satisfactorily by one normal distribution with a mean at about + 0.50 and reaching to about −5.00 D. and by one or more distributions covering higher degrees of myopia. This main portion may be called the α group and, in addition to cases of myopia up to 5.00 D., presumably includes the greater number of hyperopes, although the present data do not permit limits to be set.

(b) Relying upon the same assumptions as those used in postulating a normal distribution for the α group, a second distribution may be postulated with a mean between −3.00 and −5.00 D. and ranging from about 0.00 to approximately −8.00 D. This may be called the β group. If this is done, a third, or γ, group will be necessary to account for some of the higher grades of myopia. Data are insufficient to locate accurately its mean and range.

(c) Some sex differences which complicate the picture are suggested. The data are insufficient, however, for more than a suggestion that this phase of the problem be subjected to further analysis.

(d) Since there are also hyperopes of such magnitude as to not be included in the range suggested by the limits of the α group, it is necessary to assume the existence of still another group which may be called λ hyperopes. Analysis similar to that here described should be carried out for hyperopes to determine whether the distribution of those cases falling beyond the α group can be satisfactorily fitted by a single normal curve.

(e) The physical correlates of these groups may be speculated upon, but it is suggested that the letters α, β, γ, and λ be retained rather than names until such time as these correlates can be definitely established.

(f) The α group includes the great bulk of the cases and may reasonably be considered to represent the normal biological variability.

(g) The γ myopes could include those cases which formerly have been termed malignant, pathological, degenerative, congenital, etc. Investigations to determine the nature of these cases are still necessary. It is possible, also, that more than one type of myopia may be present in this group.

(h) The λ hyperopes may represent a group probably characterized by an underdevelopment of the globe, and further research to determine the nature of this anomaly is also necessary. The presence of such an anomaly has been mentioned by Donders, who stated that these persons also had facial stigmata characteristic of a general condition of arrested development. Since the existence of such a group has only been inferred in the present study, little can be stated at this time.

(i) It is in postulating the existence of such a group as the β myopes that the present hypothesis is most at variance with others. The γ group would correspond to the cases of more than 6.00 D. of myopia which Tron omitted from his calculations. The β myopes, λ hyperopes, and α group represent the group formerly held to exhibit a normal distribution. This assumption on which the dual categorization of Tron and Stansbury is based seems to be at variance with the empirical data here presented, a fact which also showed up in the empirical data of Titoff. The physical correlate of this group may prove to be very interesting and may possibly be the explanation of a great deal of the contradictory findings reported in the past. The present author is in complete agreement with the following statement made by Stansbury: "The factor of heredity is a representative example (of the confusion resulting from failure to classify myopia into more than one type). . . . Many surveys showing varying frequencies of familial histories have been reported but without any qualification as to type of myopia. In spite of all the work done on the heredity of myopia, it is still impossible to draw any reliable conclusions."

It may well be that this group of β myopes represents a group whose anomaly is hereditary. Numerous theories based upon glandular imbalances of one sort or another have in the past been proposed, and, as in the case of heredity, evidence has never been conclusive. This may

be due to the fact that only those myopes in the β group have whatever anomaly it is that is being considered.

PRACTICAL APPLICATIONS

It is possible to set up from the data here being considered tentative tables for the expectancy of a myope of a given degree falling within any of the three tentative classifications here suggested. That is to say, for 100 myopes of a given degree, we can predict how many of these might be expected to be in the α group and how many in the β group and how many in the γ group. Such a table has been set up (Table I). The numbers represent the number of cases per hundred who might be expected to fall within given groups.

TABLE I

Approximate percentages of possible types of myopia.

Degree of Myopia	*Males*			*Females*		
	α	β	γ	α	β	γ
1.00	97	3	—	100	—	—
2.00	88	12	—	89	11	—
3.00	60	40	—	31	69	—
4.00	25	75	—	1	99	—
5.00	2	98	—	—	100	—
6.00	—	72	28	—	20	80
7.00	—	44	56	—	?	?
8.00	—	23	77	—	—	100
9.00	—	?	?	—	—	100
10.00	—	—	100	—	—	100

As has been stated, these results are very rough and are based upon a relatively small sample. However, they may serve the purpose of checking future hypotheses. For example, in considering heredity, if it were found that among males approximately 3 per cent of the 1.00 D. myopes demonstrate hereditary causation, 12 per cent of the 2.00 D., 40 per cent of the 3.00 D., 75 per cent of the 4.00 D., and nearly all of the 5.00 D. myopes, then there would be strong evidence to indicate the presence of a separate group, the β group, whose myopia has a hereditary basis. If similar figures were found for those having a given glandular condition, this might be considered as giving indication of a separate type of myopia. It is here stressed that the figures presented in Table I are only rough approximations and are only as good as the rough methods here used. The table is in no way presented as a final statement of relative percentages of the various types of myopia, but it is designed merely to afford future researchers a basis for a working hypothesis. It represents a statistical approximation with which future clinical research may be correlated.

SUMMARY

There is good agreement among the proponents of a biological theory of myopia causation that more than one type of myopia exists. Clinically, a number of types of myopia have been described (Duke-Elder, 1949; Hirsch, 1949). However, formerly, on somewhat arbitrary grounds a dual classification was postulated. The present study represents an attempt to reconcile the clinical observation of several types of myopia with a statistical hypothesis. The evidence presented demonstrates the possibility of three or more types of myopia. The problem is such that statistical proof based upon curve fitting is extremely difficult, and further advances will probably result from clinical studies. The present paper offers a statistical justification for the clinical observation of more than two types of myopia and, also, offers a rough estimate based upon statistical analysis of the percentages of three clinical types. While in no way exact, these figures may serve as a starting point for future investigations.

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ABSTRACTS

MODERN DEVELOPMENTS IN SUBJECTIVE REFRACTION ROUTINES. A. E. Turville. Optics. (Glasgow, Scotland.) June, 1950. Pages 2-8.

This paper deals with the subjective Turville infinity balance test. This technique was devised by Turville to determine at 6 M. the faulty relationship between the vision of the two eyes and imbalances of the accommodative-convergence relationship as these affect vision. The test has proved most useful to British optometrists where it has become widely used. The author presents the techniques suggested by him to accompany the mirrors and charts required. Seven figures.

C. C. K.

AN EXPERIMENTAL STUDY ON THE CROSS-CYLINDER TECHNIQUE*

Henry J. Frank†
Chicago College of Optometry
Chicago, Illinois

The purpose of this paper is to report the investigation of several methods of using the cross cylinder in the subjective examination and the comparison of these findings.

I. PREVIOUS RESEARCH

The previous research on the cross cylinder as reported by other investigators has been concerned chiefly with its physiology. A review of the literature by the writer does not reveal any group measurements performed to determine the effects of degree of blur or amount of accommodation as determined by cross cylinder findings.

II. DESCRIPTION OF INVESTIGATION

A. *Subjects*

One hundred and eight subjects who were students of the Junior II Class at the Chicago College of Optometry were used in the study. They performed the standard subjective examination on each other under the supervision of their instructor, making deviations in the standard technique outlined later in this paper.

B. *Instruments Used*

In all cases, phoropters and phorometers at the college clinic were used. The charts used were Green test cabinets.

C. *Technique Used*

1. The standard technique of performing subjective examination as taught by the instructor was as follows:

1. Occlude the left eye and blur the right eye in plus .25 D.S. steps to the point where the 20/200 letter is barely discernible.

2. Reduce the blur in 0.25 D.S. steps until the patient can just make out the 20/50 line of letters.

3. Introduce and explain the clock-dial chart. The subject fixates the center of the dial and reports if any spokes appear darker or clearer than the rest. If the spokes appear to be the same, the spherical power is varied in 0.25 diopters steps up to 0.75 D. in either direction (plus

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or minus) directing the patient to report a difference in the spokes after each change. This is extremely important if there are previous indications of the presence of astigmatism. If spokes remain equal throughout the spherical changes, astigmatism is assumed to be absent.

4. Should any spokes appear darker or clearer, the axis of the correcting cylinder is placed at right angles to the darkest spoke. In the event two spokes are equal an axis is selected which is half way between the two axes.

5. Add minus cylinders in 0.25 D. steps until all the lines are reported equal.

6. Refer the patient back to the 20/50 line of letters and all plus sphere in 0.25 D. steps until the line is blurred out.

7. Reduce the sphere in 0.25 D. steps until the patient can read the 20/30 line of letters clearly. The 20/20 line must be blurred so that it is still difficult to read.

8. Direct the patient's attention to the 20/30 line of letters and place a cross cylinder so that the handle of the cross cylinder is parallel to the tentative axis determined by the clock dial (step 4).

9. Explain the action of the cross cylinder on the letters of the 20/30 line to the patient. That is, as the cross cylinder is flipped from first to second position, the letters may appear less blurred in one position than the other. Instruct the patient to report which position is less blurred, or, if equal blur is seen.

10. Flip the cross cylinder. If the patient reports one position less blurred or distorted than the other, move the tentative axis of the correcting cylinder in the direction of the red dots of the cross cylinder when it is in the preferred position (about 5°). Again flip the handle of the cross cylinder parallel to the new tentative axis and repeat until the patient reports that both positions of the cross cylinder produce an equal blur or distortion of the 20/30 line of letters. Check the response of equal blur distortion by moving the axis of the cylinder 5° in both directions and checking with cross cylinder in the above method. The responses for both will indicate if the original axis is correct.

11. Having now determined the proper axis of the correcting lens place the cross cylinder so that the red or white dots will be parallel with the new cylinder axis.

12. Directing the patient to the 20/30 line of letters again, flip the cross cylinder asking the patient if position one or position two causes the 20/30 line to appear clearer.

13. Should the patient report the letters clearer with the red dots parallel, increase the minus power of the correcting cylinder in

be due to the fact that only those myopes in the β group have whatever anomaly it is that is being considered.

PRACTICAL APPLICATIONS

It is possible to set up from the data here being considered tentative tables for the expectancy of a myope of a given degree falling within any of the three tentative classifications here suggested. That is to say, for 100 myopes of a given degree, we can predict how many of these might be expected to be in the α group and how many in the β group and how many in the γ group. Such a table has been set up (Table I). The numbers represent the number of cases per hundred who might be expected to fall within given groups.

TABLE I

Approximate percentages of possible types of myopia.

Degree of Myopia	*Males*			*Females*		
	α	β	γ	α	β	γ
1.00	97	3	—	100	—	—
2.00	88	12	—	89	11	—
3.00	60	40	—	31	69	—
4.00	25	75	—	1	99	—
5.00	2	98	—	—	100	—
6.00	—	72	28	—	20	80
7.00	—	44	56	—	?	?
8.00	—	23	77	—	—	100
9.00	—	?	?	—	—	100
10.00	—	—	100	—	—	100

As has been stated, these results are very rough and are based upon a relatively small sample. However, they may serve the purpose of checking future hypotheses. For example, in considering heredity, if it were found that among males approximately 3 per cent of the 1.00 D. myopes demonstrate hereditary causation, 12 per cent of the 2.00 D., 40 per cent of the 3.00 D., 75 per cent of the 4.00 D., and nearly all of the 5.00 D. myopes, then there would be strong evidence to indicate the presence of a separate group, the β group, whose myopia has a hereditary basis. If similar figures were found for those having a given glandular condition, this might be considered as giving indication of a separate type of myopia. It is here stressed that the figures presented in Table I are only rough approximations and are only as good as the rough methods here used. The table is in no way presented as a final statement of relative percentages of the various types of myopia, but it is designed merely to afford future researchers a basis for a working hypothesis. It represents a statistical approximation with which future clinical research may be correlated.

SUMMARY

There is good agreement among the proponents of a biological theory of myopia causation that more than one type of myopia exists. Clinically, a number of types of myopia have been described (Duke-Elder, 1949; Hirsch, 1949). However, formerly, on somewhat arbitrary grounds a dual classification was postulated. The present study represents an attempt to reconcile the clinical observation of several types of myopia with a statistical hypothesis. The evidence presented demonstrates the possibility of three or more types of myopia. The problem is such that statistical proof based upon curve fitting is extremely difficult, and further advances will probably result from clinical studies. The present paper offers a statistical justification for the clinical observation of more than two types of myopia and, also, offers a rough estimate based upon statistical analysis of the percentages of three clinical types. While in no way exact, these figures may serve as a starting point for future investigations.

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12. Directing the patient to the 20/30 line of letters again, flip the cross cylinder asking the patient if position one or position two causes the 20/30 line to appear clearer.

13. Should the patient report the letters clearer with the red dots parallel, increase the minus power of the correcting cylinder in

0.25 D. steps and repeat the test after each addition until the flipping of the cross cylinder will cause an equal blur or distortion in the 20/30 line of letters. Conversely, if the white dots are parallel and the letters appear clearer, reduce the minus power of the correcting cylinder in 0.25 D.S.

14. Having now determined the amount of the correcting cylinder remove the cross cylinder and direct the patient to the 20/20 line of letters. Add plus in 0.25 D.S. steps until a blur is produced of the 20/20 line of letters.

15. Reduce the plus sphere by 0.25 D. steps until the 20/20 line is sharp and distinct and, (a) the increase of plus 0.25 D.S. should produce a slight haze of the 20/20 line of letters, (b) the decrease of 0.25 D.S. will not improve the clarity of the 20/20 line of letters.

2. The experiments employed the following technique:

a. Test I (Standard Technique):

Use 20/30 line and refine cylinder and axis and power. Record finding while patient still views 20/30. Ask patient whether 20/20 line is clear. Since the patient is in a slight fog, accommodation is assumed to be inhibited. Record answer.

b. Test II (First Deviation):

Obtain 20/20 visual acuity. Return to 20/30 line as testing target and use flip cylinder to determine the cylinder axis and power. The same line is used for testing as in standard technique but now accommodation is in use. Record answer.

c. Test III (Second Deviation):

Obtain best possible visual acuity (20/15). Use this line as testing target and use the flip cylinder to determine the cylinder axis and power. Record this finding.

III. FINDINGS

On solving for power, the results were as follows:

Test	$\overline{M}$ (Mean)	(Sigma)	Sm (Sigma mean)	Critical Ratio	
I	+ .05	.57	.06	.006	
II	.00	.56	.06		.01
III	− .04	.56	.06	.005	

When solving for axis: The findings were first considered under "with the rule" and "against the rule" astigmatism. These findings were identical:

Test	$\overline{M}$	Sigma	Sm	Critical Ratio	
I	93.25	9.84	1.16	1.45	
II	91.20	6.57	.79		1.25
III	91.78	1.79	.22	.70	

IV. CONCLUSION

In conclusion, it may be stated that the critical ratios between tests I, II, and III, as far as power of the cylinder is concerned, are insignificant and it therefore appears that the power of the cylinder can be obtained under slight blur, 20/20 visual acuity, or best visual acuity without changing the results.

However, the results obtained when checking for axis reveal that the sigma of $\pm$ 9.84 in the standard test (I) could give a deviation of 19.68° in axis. In test II, the sigma of $\pm$ 6.57 could give a difference of 13.14°. In test III, the sigma $\pm$ 1.79 could give a difference of 3.58°. For this reason, it would seem advisable to perform the flip cylinder test under best visual acuity.

Thanks of the writer go to the personnel of the Chicago Strabismus Research Project, and to my students without whose help this investigation could not have been conducted.

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[4]A Possible Fallacy in the Use of the Cross Cylinder. F. A. Williamson-Noble. The British Journal of Ophthalmology, January, 1943.

ABSTRACTS

JOINT PLANNING BY THE AMERICAN ACADEMY OF PEDIATRICS AND THE AMERICAN PUBLIC HEALTH ASSOCIATION FOR THE DEVELOPMENT OF SCHOOL HEALTH SERVICES. T. E. Shaffer. Am. J. of Public Health. 40.63-66. Jan. 1950.

Although there have been appreciable advances in the health services which have benefited infants and pre-school children nevertheless, the point is made that progress has not been so great in health care for the school-age child. However, two events in 1949 indicate an expansion of health services for these childrens one is the support given throughout the nation and in Congress for the National School Health Services Act, and the other is the comprehensive Report of the Study of Child Health Services, published in April by the Commonwealth Fund.

The findings of this study confirm the need for more health facilities for children 5 to 17 years of age, and disclose the disturbing fact that the bulk of medical services in schools having a health program are in the hands of physicians not especially qualified, either through experience or training, in the health supervision of children.

It is pointed out that school health services cannot be carried out by any one professional group, and it is hoped that well-qualified individuals—dentists, nurses, pediatricians, etc.—will be interested in taking part in local programs.

The author stresses the need for proper health supervision of children today because of "the magnitude of their undiscovered needs." In conclusion, he states: "It is urgent that this be done now, lest the professions in health and education be unprepared to meet a growing petition for better services.

"If a pattern could thus be established which would encourage similar point planning between public health agencies, educators, and specialists in child health at state and community levels, the future of school health would be assured."

R. E. B.

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EDITORS AND STAFF

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COMMENTS ON RECENT BOOKS

Ida Mann, one of Great Britain's foremost ophthalmologists, has just come out with a new edition of her valued work, *Development of the Human Eye*.[1] The first edition, now long out of print, appeared in 1928, and the new revised edition will give many of the younger eye men an opportunity to add this classic on the anatomical development of the eye to their libraries. Mann's text is basic for all ocular study. It is not light reading and may not appeal to those who are only engrossed in manipulating space. It will nevertheless find a very ready market among the serious thinkers in optometry and ophthalmology.

State Board Questions and Answers[2] by Harry Pine, appeared in October. The author of this compilation is a past president of the

American Optometric Association and one of optometry's most force ful leaders. From thousands of board questions and answers he has selected representative questions in each of the seven categories used by our official examiners. The text will be of particular value to senior students who are about to take their state board examinations in optometry. As usual, Pine has done a fine job with this material.

Derrick Vail, ophthalmologist, Northwestern University, has just come out with his version of what the public should know about eyes entitled, *The Truth About Your Eyes.*[3] This is a well written lay text, and in general, follows the orthodox lines accepted by most optometrists and ophthalmologists. To be sure, Vail apparently could not resist a few digs at optometry, and he attempts to revive the drops question, but with no telling effect. He naturally and properly has little sympathy for eye exercises in the correction of myopia or color vision defects. Surprisingly, he finds little use for absorptive lenses in average refractive cases despite the pleasure these afford so many users. Some believe this book was rushed into print to offset the widespread effect of *New Ways to Better Sight* by Harris Gruman.

Now in its second edition, Gruman's *New Ways to Better Sight*[4] is fast becoming a best seller. This book, like Vail's, is aimed at lay readership and is sold direct to the public. Optometrists have used the book effectively in reception rooms and public libraries. All reference rooms should be equipped with this text. More good work in this direction can still be done and local societies should make sure the Gruman book is on hand wherever it will be of value to students and lay persons interested in factual data relating to their eyes.

A more serious new text is *Recent Advances in the Physiology of Vision*[5] by Hamilton Hartridge, who covers the field of physiology of vision in a very thorough manner. The author is a British professor and his references are largely from British and Continental material, although some of the later American writers are quoted. This book, like Mann's, deals with the basic science upon which the framework of refractive procedure rests. The price is surprisingly low for a text of this size and quality.

Some 30 writers, each experienced in the problems of the blind, have produced a new volume, *Blindness.*[6] This material was edited by Paul A. Zahl and published under the auspices of the National Research Council. Some of the authors are blind themselves; others are professional social workers, psychologists, ophthalmologists and welfare workers who have studied the problems of the blind. The book covers selected material on the history and welfare of the blind, the educational

and vocational considerations afforded the blind and the aids to the blind. While it does not deal with corrective procedures at all, there is a great deal in the text of interest to everyone dealing with eye care.

CAREL C. KOCH.

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[1]Mann, Ida. The Development of the Human Eye. Grune & Stratton, Inc., New York City. 312 pp. Illustrated. $6.50. 1950.
[2]Pine, Harry E. State Board Questions and Answers. The Professional Press, Inc., Chicago, Illinois. 136 pp. Not illustrated. $3.50. 1950.
[3]Vail, Derrick. The Truth About Your Eyes. Farrar, Straus & Co., New York City. 180 pp. Illustrated. $2.50. 1950.
[4]Gruman, Harris. New Ways to Better Sight. Shayne-Dell Press, Lebanon, Pennsylvania. 207 pp. Illustrated. $3.50. 1950.
[5]Hartridge, Hamilton. Recent Advances in the Physiology of Vision. The Blakiston Co., Philadelphia, Pa. 399 pp. Illustrated. $5.00. 1950.
[6]Zahl, Paul A. Blindness. Princeton University Press, Princeton, New Jersey. 576 pp. Illustrated. $7.50. 1950.

TRANSACTIONS OF THE AMERICAN ACADEMY OF OPTOMETRY

A department devoted to announcements, reports, appointments, organization data, news, professional problems and ideals, as these relate to the Academy.

PROGRAM OF ANNUAL MEETING OF ACADEMY

December 16-17-18-19, 1950

The Drake Hotel, Chicago, Illinois

Saturday, December 16, 1950

9:00-10:00 A. M. ..... Registration

10:00 ..... Business Session

Reports by officers and committee chairmen.

11:00 ..... Pathology Section

"Endocrine Disturbances and Their Effects Upon the Eyes." Isadore Kaplan, M.D., Pennsylvania State College of Optometry, Philadelphia, Pennsylvania.

1:30 P. M. ..... Lecture

"Visual Functions as Indices of Physiological Changes." Charles Hendley, Ph.D., School of Optometry, Ohio State University, Columbus, Ohio.

2:15 P. M. ..... Lecture

"Some Psychological Factors of Flicker and Fusion." George W. Knox, Ph.D., School of Optometry, Ohio State University, Columbus, Ohio.

3:00 P. M. ..... Lecture
"A Study of the Flattening Effect Produced by Optical Magnification." S. Howard Bartley, Ph.D., Michigan State College, East Lansing, Michigan.

3:45 P. M. ..... Lecture
"The Prescription of Base-in Prisms." George A. Parkins, O.D., Ord, Nebraska.

4:30 P. M. ..... Lecture
"The Optometrist and War-time First Aid." John C. Neill, O.D., Pennsylvania State College of Optometry, Philadelphia, Pennsylvania.

8:00 P. M. ..... Lecture
"Subjective Appraisal of Brightness." Sylvester A. Guth, General Electric Company, Nela Park, Cleveland, Ohio.

8:45 P. M. ..... Lecture
"Trifocal Lenses, A Clinical Study Based Upon 22,640 Prescriptions." Robert E. Bannon, O.D., Hanover, New Hampshire.

Sunday, December 17, 1950

9:00 A. M. ..... Section Meetings
Aniseikonia, Contact Lenses, Orthoptics.

11:00 ..... Pathology Section
"Headaches." Part I. Harold Simmerman, O.D., Pennsylvania State College of Optometry, Philadelphia, Pennsylvania.

1:30 P. M. ..... Lecture
"Accommodation and Convergence in a Patient With Adie's Pupil." Meredith W. Morgan, Jr., Ph.D. and Robert Harrigan, O.D., School of Optometry, University of California, Berkeley, California.

2:15 P. M. ..... Lecture
"Factors Related to Monocular and Binocular Reading Efficiency." Helen M. Robinson, Ph.D., University of Chicago, Reading Clinics, Chicago, Illinois.

3:00 P. M. ..... Lecture
"Some Aspects of the Psychology of Binocular Vision." The Lord Charnwood, The Refraction Hospital, London, England.

3:45 P. M. ..... Lecture
"Operational Analysis of Optometric Concepts." Eugene Freeman, Ph.D., Chicago College of Optometry, Chicago, Illinois.

4:30 P. M. ..... Lecture
"One Hundred Years the Ophthalmoscope, von Helmholtz, the

Man, His Life, and His Work." William P. Schumann, O.D., Vineland, New Jersey.

8:00 P. M. ..... Lecture
"Compensatory Cyclo-Torsion and Visual Acuity." William G. Walton, Jr., O.D., Pennsylvania State College of Optometry, Philadelphia, Pennsylvania.

8:45 P. M. ..... Lecture
"Public Relations in Optometry, As Viewed By a College Dean." Richard Feinberg, Ph.D., College of Optometry, Pacific University, Forest Grove, Oregon.

Monday, December 18, 1950

9:00 A. M. ..... Section Meetings
Aniseikonia, Orthoptics, Contact Lenses.

11:00 ..... Pathology Section
"Scleral Tonometry." Henry L. Wolfe, O.D., Marshalltown, Iowa.

1:30 P. M. ..... Lecture
"Effect of School Experience on Refraction of Children." Monroe J. Hirsch, Ph.D., Los Angeles College of Optometry, Los Angeles, California.

2:15 P. M. ..... Lecture
"Simple Method for Evaluating Adaptness for Color Recognition in Industry." William Smith, O.D., Massachusetts College of Optometry, Boston, Mass.

3:00 P. M. ..... Lecture
"Effect of Aniseikonia on the Amplitude of Vertical Divergence." Vincent J. Ellerbrock, Ph.D., School of Optometry, The Ohio State University, Columbus, Ohio.

3:45 P. M. ..... Lecture
"Relationship of Proximal Convergence To Fusional and Accommodative Convergence." Henry W. Hofstetter, Ph.D., Los Angeles College of Optometry, Los Angeles, California.

4:30 P. M. ..... Business Session

7:00 P. M. ..... Annual Formal Banquet
Speaker, Henry A. Imus, Ph.D., Office of Naval Research, Washington, D. C., "Fundamental Research in Vision."

Tuesday, December 19, 1950

9:00 - 11:00 A. M. ..... Section Meetings
Aniseikonia, Orthoptics, Contact Lenses.

11:00 ..... Pathology Section
"Headaches." Part II, Harold Simmerman, O.D., Pennsylvania State College of Optometry, Philadelphia, Pennsylvania.
Noon ..... Chapter Luncheon
2:00 P. M. ..... Lecture
"Counselling in Ocular Genetic Problems." Harry Jankiewicz, Ph.D., Los Angeles College of Optometry, Los Angeles, California.
2:45 P. M. ..... Lecture
"Industry and the Optometrists." Roy Marks, O.D., Bausch & Lomb Optical Company, Rochester, New York.
3:30 P. M. ..... Lecture
"The Problem of Eyelessness Among Cave Animals." Arthur Schlaifer, Ph.D., Pennsylvania State College of Optometry, Philadelphia, Pennsylvania.
4:15 P. M. ..... Lecture
"Gearing Optometry to the Atomic Era. A Blueprint for 1951-1999." Ernest A. Hutchinson, O.D., Los Angeles College of Optometry, Los Angeles, California.
5:00 P. M. ..... Lecture
"State of Optometry in Britain." R. A. Phillips, Lee, S. E., London, England.
5:45 P. M. ..... Closing Session

LOCAL CHAPTER ACTIVITIES

SOUTHERN CALIFORNIA

Friday the thirteenth was no bugaboo for Southern California Fellows. They made October 13 "homecoming day" and gathered to hear Dr. Henry Knoll discuss night myopia. His lecture was based on his experience in the U. S. Navy where he conducted research in vision at low levels of illumination.

UPSTATE NEW YORK FORMS NEW CHAPTER

Fellows in Upstate New York held an organizational meeting for a new chapter October 29. The meeting took place in the B & L eye clinic, Rochester. In addition to taking care of business problems, members heard three lectures: Dr. Nathan Robbins on "Cross Cylinder Findings at Distance"; Dr. N. Bergman (Bausch & Lomb staff member), "The Operation of an Industrial Eye Clinic," with a conducted tour of the clinic; Dr. Fred Jobe, "The Visual Characteristics of Adults in Industry."

MARYLAND CHAPTER

The Maryland Chapter of the Academy held a dinner meeting in

Baltimore on October 19. The evening was spent discussing optometric procedures and practice.

CURRENT COMMENTS

Virginia Huck
Editorial Assistant

Optometrists will confer a favor by sending news items of general interest for this department; such as relate to new instruments, clinical techniques, education, visual health and optometric legislation and organization.

NATIONAL INTERPROFESSIONAL COMMITTEE ON EYE CARE

A national interprofessional committee dedicated to improving the quality of eye care supplied the public, and strengthening interprofessional relations has been organized, and held its first meeting in Chicago on October 8.

The committee is comprised of representatives of various societies in the fields of ophthalmology, optometry and opticianry, and has been named the "National Interprofessional Committee on Eye Care."

At this first meeting at the Palmer House, held concurrently with the annual meeting of the American Academy of Ophthalmology and Otolaryngology, officers were elected and agenda drawn up for future discussion by the committee.

Dr. Avery D. Prangen, ophthalmologist, Mayo Clinic, Rochester, Minnesota, was chosen chairman for the coming year, and Mr. Leslie Myers, chairman of the Board, Benson Optical Company, Minneapolis, vice chairman. Elected Secretary was Dr. Carel C. Koch, Editor, *American Journal of Optometry* and Secretary of the American Academy of Optometry.

Other members of the committee, in addition to the above-named officers, are Mr. Henry B. Carpenter, Guild optician, Syracuse, New York; Dr. Frederick C. Cordes, professor of ophthalmology, University of California, San Francisco; Dr. Arthur M. Culler, professor of ophthalmology, Ohio State University, Columbus, Ohio; Dr. H. Ward Ewalt, Jr., optometrist, Pittsburgh, Pennsylvania; Dr. Franklin M. Foote, executive director, National Society for the Prevention of Blindness, New York, New York; Dr. Henry A. Imus, physicist, Office of Naval Research, Washington, D. C.; Mr. Norman A. MacLeod, wholesale optician, Providence, Rhode Island; Dr. Glenn H. Moore, optometrist, Chicago, Illinois. Dr. William F. Hughes, Jr., professor of ophthalmology, University of Illinois, Chicago, Illinois, will also serve on the committee as alternate.

Problems discussed at this first session included, besides organization, interprofessional relationships and various other topics relating to improving the optical eye care offered to the public by the several groups comprising the committee. In general, the public health aspects of optical eye care were stressed.

The second meeting of the National Interprofessional Committee on Eye Care is scheduled for December 17, in Chicago, and will be held concurrently with the annual meeting of the American Academy of Optometry.

GRANTS

Dr. Daniel Woolf of New York City and Dr. Neal J. Bailey of Escanaba, Michigan, were recently awarded research fellowships by the American Optometric Foundation. A research grant for studying visual problems connected with viewing television has also been granted, according to Dr. William Ezell, Foundation president.

Dr. Woolf will study the mechanism of accommodation at the School of Optometry, Columbia University; Dr. Bailey has chosen as his project, "Does the Anomalous Projector Have a Single or a Double Point of View of the World?" and will conduct his study at the School of Optometry, Ohio State University.

The study of television effects on eyes will be made at the Los Angeles College of Optometry. Visual fatigue, visual acuity, blink rate and the relation of ametropia to television viewing difficulties are among the factors to be investigated.

* * * *

The National Society for the Prevention of Blindness has announced a research grant of $2,500.00 to the New York University-Bellevue Medical Center to study retrolental fibroplasia. The grant was prompted by the sharp increase in the number of premature infants being blinded by the disease, according to Dr. Franklin M. Foote, executive director of the Society.

OPTOMETRISTS IN THE NEWS

Dr. Harold M. Fisher, past president of the American Academy of Optometry, and faculty member of the School of Optometry, Columbia University, has become associated with Dr. E. LeRoy Ryer in private optometric practice in New York City. Dr. Fisher has taken the place of Dr. Elmer E. Hotaling, who died last July.

Dr. William Smith, Boston, Massachusetts, has been invited to be on the program of the coming International Optical Congress in London, July 9. Mr. W. E. Hardy, Editor of the *Optician*, London, extended the invitation.

Dr. W. S. Long, R.O., Toronto, Ontario, Canada, has taken over the editorship of the *Canadian Journal of Optometry*, since the death of Dr. Edward Bind, Secretary of the Canadian Optometric Association, and leader in Canadian optometric affairs for the past 25 years. Dr. Long is a member of the faculty of the Ontario College of Optometry.

Dr. Carel C. Koch, Editor, *American Journal of Optometry*, has been appointed by Major General Lewis B. Hershey, Director, Selective Service System, Washington, D. C., to represent optometry on the Selective Service scientific advisory committee dealing with the healing arts. Other members of the committee are Dr. Stockton Kimball, School of Medicine, University of Buffalo, representing medicine, chairman; Dr. Walter R. Krill, College of Veterinary Medicine, the Ohio State University, representing veterinary medicine; Dr. R. McFarland Tilley, American Osteopathic Association, representing osteopathy, and Dr. Gerald T. Timmons, School of Dentistry, Temple University, representing dentistry. The advisory committee on the healing arts met with General Hershey November 2 at Washington.

B. V. I. PLANS 1951 CAMPAIGN

John Q. Public has a chip on his shoulder. He feels he is being overcharged for ophthalmic services.

This situation was pointed out at the recent quarterly meeting of the Better Vision Institute, and board members pledged themselves to knock the chip off John Q.'s shoulder in 1951. An extensive eight-point campaign was outlined:

1. To bring out the fact that faulty vision is harmful, handicapping.
2. To attack false consumer notions and prejudices about ophthalmic services, skills, and prices.
3. To counteract harmful propaganda on costs, rebates, and services.
4. To teach that visual care in the United States gives most, costs least.
5. To teach that visual care is the biggest bargain in the family budget.
6. To feature the Institute slogan, "Nothing you buy gives you so much, yet costs you so little."
7. To stress the complex sciences, skills, and crafts that combine to produce the finest visual service in the world.
8. To deal with the major fields of visual interest, namely school children, factory workers, and automobile drivers.

Recognizing that such a campaign is a man-sized job and will

need more funds than are now available, B. V. I. also planned to launch a new membership drive.

If the needed funds are subscribed, the educational campaign will be carried on full scale to counteract the unjustified stigma of "high prices" now attached to the ophthalmic field by the public.

NEWS BRIEFS

Psychiatrist Joseph J. Galler of Paterson, New Jersey, was guest speaker at the recent quarterly meeting of the New Jersey Optometric Association. He talked on "The Psychological Mechanisms Causing Headaches." . . . Soft-Lite's *Practice Builder*, a magazine devoted to practice building ideas, celebrated its 15th year of publication with a special anniversary issue showing there's been little change in basic ideas for practice building since 1935. . . . Eighty new students enrolled this fall in Northern Illinois College of Optometry, now in its 80th year of operation. . . . A new optometric case study report is now available through the Pacific University School of Optometry. The School will furnish information and samples on request. . . . Columbia University's School of Optometry is now headquartering at 132 West 60th Street, New York 23, New York. . . . Univis Lens Company is expanding. Construction of a new plant is now getting under way at Guayama, Puerto Rico. . . . Shuron Optical Company has again joined the ranks of national advertisers, calling attention to visual problems, and the need for proper eye care. Their new copy and layout is attention-getting. . . . November is American Optometric Foundation month, and directors are hoping it will be a record month for new members. Every new member means progress in research for optometry, for the Foundation is dedicated to promoting research and education in the profession. Contact Dr. William C. Ezell, President, 205 Andrews Building, Spartanburg, South Carolina, for membership information. . . . The fall bulletin of the Aniseikonic Forum is out, with news of interest to all practitioners. Dr. Paul Boeder, who presented a paper at the International Congress of Ophthalmology in London last July on aniseikonia, reports very favorable attention to the aniseikonic exhibition. "The aniseikonic exhibition in the scientific section was accorded a reception such as I had not dared dream of," says Dr. Boeder. "Many who had experienced the spatial distortions were eager to demonstrate them to others. Sometimes there were no less than 15 to 20 people crowding the exhibit. No other spot in the entire scientific exhibition received similar attention." . . . November 3rd marked Bausch & Lomb's 98th year of business. Plans are now under way at Rochester, New York, for the 100th anniversary celebration in 1952-1953.

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The booklet is the instruction manual supplied with the Lancaster astigmatic Dials but it may be ordered separately.

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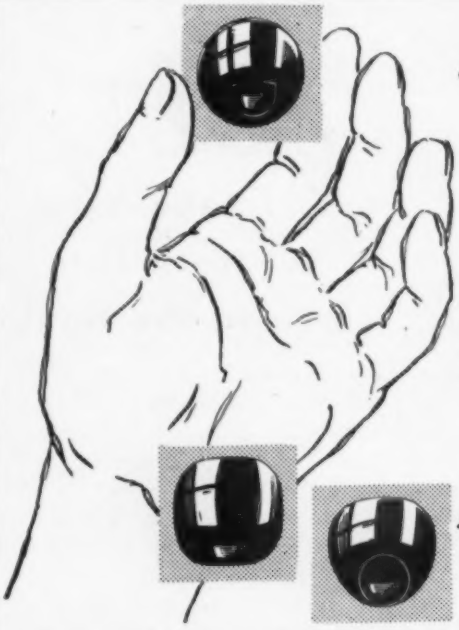

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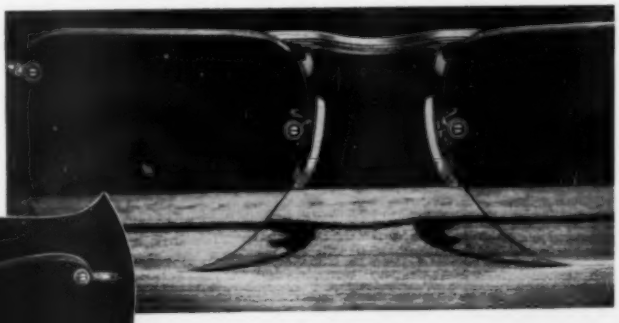

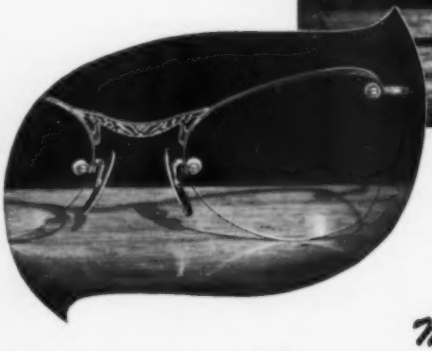

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by

Solve Stenstrom, M.D.

Translated from the original German by

Daniel Woolf, O.D.
School of Optometry, Columbia University, New York, New York

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